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# NAVAL POSTGRADUATE SCHOOL
## Monterey, California




# THESIS

INTRODUCTION TO THE MICROCOMPUTERS FOR SOLVING RADAR ELECTRONIC WARFARE PROBLEMS

by

Constantinos D. Vergos

December 1985

Thesis Advisor: Harold A. Titus

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UNCLASSIFIED
URITY CLASSIFICATION OF THIS PAGE

## REPORT DOCUMENTATION PAGE

| | |
|---|---|
| REPORT SECURITY CLASSIFICATION<br>Unclassified | 1b. RESTRICTIVE MARKINGS |
| SECURITY CLASSIFICATION AUTHORITY | 3 DISTRIBUTION / AVAILABILITY OF REPORT<br>Approved for public release; distribution is unlimited |
| DECLASSIFICATION / DOWNGRADING SCHEDULE | |
| PERFORMING ORGANIZATION REPORT NUMBER(S) | 5. MONITORING ORGANIZATION REPORT NUMBER(S) |
| NAME OF PERFORMING ORGANIZATION<br>aval Postgraduate School | 6b. OFFICE SYMBOL (If applicable)<br>Code 62 |
| 7a. NAME OF MONITORING ORGANIZATION<br>Naval Postgraduate School | |
| ADDRESS (City, State, and ZIP Code)<br>onterey, California 93943-5100 | 7b. ADDRESS (City, State, and ZIP Code)<br>Monterey, California 93943-5100 |
| NAME OF FUNDING / SPONSORING ORGANIZATION | 8b. OFFICE SYMBOL (If applicable) |
| 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER | |
| ADDRESS (City, State, and ZIP Code) | 10. SOURCE OF FUNDING NUMBERS |

| PROGRAM ELEMENT NO. | PROJECT NO | TASK NO | WORK UNIT ACCESSION NO. |
|---|---|---|---|
| | | | |

TITLE (Include Security Classification)
INTRODUCTION TO THE MICROCOMPUTERS FOR SOLVING RADAR AND ELECTRONIC WARFARE PROBLEMS

PERSONAL AUTHOR(S)
Vergos, Constantinos D.

| TYPE OF REPORT | 13b TIME COVERED | 14 DATE OF REPORT (Year, Month, Day) | 15 PAGE COUNT |
|---|---|---|---|
| ster's Thesis | FROM _____ TO _____ | 1985, December | 251 |

SUPPLEMENTARY NOTATION

| COSATI CODES | | |
|---|---|---|
| FIELD | GROUP | SUB-GROUP |
| | | |
| | | |

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
MTI radar, AMTI, Doppler, Microcomputers; Radar and Electronic Warfare, COSRO, CONSCAN,

ABSTRACT (Continue on reverse if necessary and identify by block number)

This thesis has been written to solve different types of problems through microcomputers in the radar and electronic warfare field. These problems are offered as subjects at the Naval Postgraduate School in Courses EC 4432/33, EC 4484, and EC 3431.

The computer programs that solve these computer problems have been written in an interactive method because it is user friendly and also

| | |
|---|---|
| DISTRIBUTION / AVAILABILITY OF ABSTRACT<br>☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS | 21. ABSTRACT SECURITY CLASSIFICATION<br>Unclassified |
| NAME OF RESPONSIBLE INDIVIDUAL<br>rof. Harold A. Titus | 22b. TELEPHONE (Include Area Code)<br>(408) 646-2560 |
| | 22c. OFFICE SYMBOL<br>Code 62Ts |

FORM 1473, 84 MAR 83 APR edition may be used until exhausted
All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

#19 - ABSTRACT - (CONTINUED)

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# Introduction to the Microcomputers for Solving Radar and Electronic Warfare Problems

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL

December 1985

## ABSTRACT

This thesis has been written to solve different types of problems through microcomputers in the radar and electronic warfare field. These problems are offered as subjects at the Naval Postgraduate School in Courses EC 4432/33, EC 4484, and EC 3431.

The computer programs that solve these computer problems have been written in an interactive method because it is user friendly and also so that anyone can change any given parameter or characteristics of radars and jammers and thus study their performance for the purpose of using or designing them.

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# I. INTRODUCTION

The intent of this thesis is to solve diverse types of problems in the field of radar and Electronic Warfare, with the help of microcomputers, in order to help training officers to better understand this area of technology.

Many of our Naval Officers today have microcomputers which they take to sea with them. In addition a new MIL-SPEC Hewlett-Packard microcomputer is becoming operational on all Naval combatants. These PC's have the potential for providing an excellent resource in the tactical training of the officer in problems in electronic warfare and radar. All too often at sea these technical problems are brushed aside and left for civilian technicians. There is however a great need for the technically trained officer to be able to handle the changing technical EW radar situations. These sample problems may provide help in attacking some of the problems that the operating Naval officer will encounter.

Microsoft Basic and the interactive method have been used to write the programs that solve these problems. Microsoft Basic is an easy language for anyone to understand and as a result, the user can easily modify the programs. Also, because Microsoft Basic is available in every microcomputer, there is no need for one to make changes to run these programs on different microcomputers. The interactive method gives one the opportunity to input any chosen data and the ability, by

changing this data, to study the different performances of radar and jammers.

In solving these problems, the following have been taken into account: The performance of the radars, the ability of the radars to track targets, the design of radars for special purposes, and the design and study of different types of jammers. Special emphasis has been given to select these problems so that there would be a diverse field of different types of radars and jammers for numerous purposes, including their use in different conditions of operations. This selection of problems has been done in such a way that they can help a training officer to comprehend and perceive or to help an engineer evaluate a radar or a jammer he/she may wish to design.

In Chapter II, the author presents material which is needed to solve the problems of Chapters III and IV. A brief explanation for each equation is given as in Skolnik [Ref. 1].

The third part of this thesis encompasses problems that refer entirely to radars.

The fourth part deals with the problems of radars and jammers and how dissimilar types of jammers affect the radars, problems in which different categories of transmitting and receiving antennas are examined, and problems on different types of jamming techniques. Most of these problems have been taken from [Ref. 3].

The conclusion drawn from this software development is contained in Chapter V, Conclusion.

Appendix A lists the computer programs and outputs from the results of each radar problem of Chapter II.

The contents of Appendix B are similar to Appendix A but deal with electronic warfare problems.

## II. EQUATIONS AND FIGURES

The problems addressed here cover a wide range of questions that one might encounter in radar and EW. For example, what detection probability is required? What is the maximum range given a radar's power and target RCS? What range inaccuracies are involved when FM ranging and what problems in doppler radar occur in terms of blind spots? What improvements are gained from MTI radar in a clutter environment? How can the radar receiver power be computed, as well as the noise power, and signal-to-noise ratios? What are critical parameters in an MTI-chaff discriminator? In a phased array system, what is the beamwidth and phase shift between elements? These and many other problems are addressed.

Herein are the functional relationships in the field of radar and electronic warfare which are used to solve the problems in Chapters III and Iv. They are given with a brief description in [Refs. 1,2,3].

Maximum Unambiguous Range:

$$\text{Runamb} = \frac{C}{2f_p} \tag{1}$$

where:

$f_p$ = pulse repetition frequency, Hz;

$C$ = speed of light = $3 \times 10^8$ m/s.

The factor 2 appears in the denominator because of the two-way propagation of radar.

Maximum radar range in terms of radar and target parameters:

$$R_{max} = \left[\frac{P_t G A_e \sigma}{(4\pi)^2 S_{min}}\right] \quad (2)$$

where:

$P_t$ = transmitted power, watts;

$G$ = antenna gain;

$A_e$ = antenna effective aperture, $m^2$;

= radar cross section, $m^2$;

$S_{min}$ = minimum detectable signal, watts.

The radar equation (2) with some modifications becomes:

$$R_{max}^4 = \frac{P_{av} G A \rho_a \sigma n E_i(n)}{(4\pi)^2 k T_o F_n (B_\tau) f_p (S/N)_1 L_s} \quad (2a)$$

where:

$R_{max}$ = maximum radar range, m;

$G$ = antenna gain;

$A$ = antenna aperture, $m^2$

$\rho_a$ = antenna efficiency;

$n$ = number of hits integrated

$E_i(n)$ = integration efficiency (less than unity)

$L_s$ = system losses (greater than unity) not included in other parameters;

$\sigma$ = radar cross section of target, $m^2$

$F_n$ = noise figure;

$k$ = Boltzmann's constant = $1.38 \times 10^{-23}$ J/deg.

$T_o$ = standard temperature = 290°k

$B$ = receiver bandwidth, Hz;

$\tau$ = pulse width, s;

$f_p$ = pulse repetition frequency, Hz

$(S/N)_1$ = signal-to-noise ratio required at receiver output (based on single-hit detection).

Equation 2(a) is written in terms of power; it can also be written in terms of energy with the following modifications:

(a) The energy in the transmitted pulse is

$$E_\tau = P_{av}/f_p = P_t \tau .$$

(b) The signal-to-noise power ratio $(S/N)_1$ can be replaced by the signal-to-noise energy ratio $(E/N_o)_1$, where $E = s/\tau$ (received signal energy), and $N_o = N/B$ (noise energy).

(c) $B\tau \tilde{=} 1$, and $T_o F_n = T_s$ = system noise temerature.

Then, the radar equation 2(a) can be written as:

$$R_{max}^4 = \frac{E_\tau G A \rho_a \sigma n E_i(n)}{(4\pi)^2 k T_s) E/N_o)_1 L_s} \qquad (2b)$$

Equation 2(b) is applied to rectangular pulses, and if matched filter detection is employed, can be applied to other waveforms as well.

Thermal-noise power, generated by a receiver is:

$$N_n = k T B_n \qquad (3)$$

where:

$B_n$ = receiver's bandwidth, Hz;

$T_s$ = temperature at which the noise power is generated, degrees kelvin;

$k$ = Boltzmann's constant = $1.38 \times 10^{-23}$ J/deg.

Minimum detectable signal $S_{min}$:

$$S_{min} = k T_o B_n F_n (S_o/N_o)_{min} \qquad (4)$$

where:

$k$ = Boltzmann's constant = $1.38 \times 10^{-23}$ J/deg.;

$T_o$ = standard temperature = 290 degrees kelvin;

$B_n$ = receiver's bandwidth, Hz;

$F_n$ = receiver's noise figure;

$(S_o/N_o)_{min}$ = minimum ratio of output (IF) signal-to-noise ratio, required for detection.

False alarm probability: $Pf_a$,

$$Pf_a = \frac{1}{T_{fa} \times B_{IF}} \tag{5}$$

$$T_{fa} = \frac{1}{B_{IF}} \exp \frac{V_T^2}{2\psi_o} \tag{5a}$$

where:

$T_{fa}$ = false alarm time;

$B_{IF}$ = bandwidth of the IF amplifier;

$V_T$ = threshold voltage

$\psi_o$ = noise voltage.

Number of pulses $n_B$, returned from a point target, as the radar antenna scans through its beamwidth is:

$$n_B = \frac{\theta_B f_p}{\dot{\theta}_s} = \frac{\theta_B f_p}{\sigma w_m} \tag{6}$$

where:

$\theta_B$ = antenna beamwidth, deg.;

$f_p$ = pulse repetition frequency, Hz;

$\dot{\theta}_s$ = antenna scanning rate, deg/s;

$w_m$ = antenna scan rule, rpm.

Integration efficiency $E_i(n)$,

$$E_i(n) = \frac{(S/N)_1}{n(S/N)_n} \tag{7}$$

where:

$(S/N)_1$ = signal-to-noise ratio of a single pulse required to produce given probability of detection (for n = 1);

$(S/N)_n$ = signal-to-noise ratio per pulse required to produce some probability of detection when n pulses are integrated at the same $P_d$ and $P_{FA}$;

n = number of pulses integrated.

False alarm number, $n_f$:

$$n_f = \frac{1}{P_{fa}} \tag{8}$$

where:

$P_{fa}$ = false alarm probability.

Collapsing loss, $L_i(m,n)$:

$$L_i(m,n) = \frac{L_i(m+n)}{L_i(n)} \tag{9}$$

where:

$L_i(m+n)$ = integration loss for (m+n) pulses;

$L_i(n)$ = integration loss for n pulses;

n = noise pulses;

m = signal-plus-noise pulses.

Doppler frequency shift, $f_d$:

$$f_d = \frac{2u_r}{\lambda} = \frac{2\,u_r\,f_o}{c} \tag{10}$$

where:

$u_r$ = relative (or radial) velocity of target with respect to radar;

$f_o$ = transmitted frequency;

c = velocity of propagation = $3 \times 10^8$ w/s

If $f_d$ is in Hz, $u_r$ in knots, and $\lambda$ in meters, then

$$f_d = \frac{1.03u_r}{\lambda} \tag{10a}$$

Beat frequency, $f_r$:

$$f_r = \dot{f}_o T = \frac{2R}{c}\dot{f}_o \tag{11}$$

where:

$\dot{f}_o$ = rate of change of the corner frequency.

Blind speeds, $u_n$:

$$u_n = \frac{n\lambda}{2T_p} = \frac{n\lambda f_p}{2} \qquad n = 1,2,3,... \tag{12}$$

where:

$f_p$ = pulse repetition frequency, Hz;

$\lambda$ = wavelength of radiated frequency, w.

If $\lambda$ is measured in meters, $f_p$ in Hz, and the relative velocity in knots, the blind speeds are:

$$u_n = \frac{n\,\lambda\,f_p}{1.02} \doteq n\,\lambda\,f_p \tag{12a}$$

Clutter attenuation, CA:

$$CA = \frac{0.5}{1 - \exp(-2\pi^2 T^2 \sigma_c^2)} \tag{13}$$

where:

$\pi$ = 3.14159;

T = time delay of the delay line;

$\sigma_c$ = rms frequency clutter spread.

If the exponent in the denominator of Eq. (13) is small, then

$$CA = \frac{a\,f_p^2}{2\pi^2 f_o^2} \tag{13a}$$

where:

$a$ = parameter dependent upon clutter = $c^2/8\sigma_u^2$;

$\sigma_u$ = rms velocity spread;

$f_p$ = pulse repetition frequency;

$f_o$ = radar carrier frequency.

Improvement factor of 2 pulse canceller,

$$I_{1c} = \frac{a f_p^2}{\pi^2 f_o^2} \tag{14}$$

Improvement factor for a double delay line canceller

$$I_{2c} = \frac{a^2 f_p^4}{2\pi^4 f_o^4} \tag{15}$$

Power antenna gain,

$$G = P_r G_D \tag{16}$$

where:

$P_r$ = radiation efficiency factor;

$G_D$ = directive gain of the antenna.

The gain G, and the effective area Ae of a lossler antenna are related by

$$G = \frac{4\pi Ae}{\lambda^2} = \frac{4\pi p_o A}{\lambda^2} \tag{16a}$$

$$Ae = p_a A$$

where:

$\lambda$ = wavelength of radiated energy, m;

A = physical area of antenna;

$p_a$ = antenna aperture efficiency.

Also, the relationship between the gain and the beamwidth of an antenna is given by

$$G \doteq \frac{20{,}000}{\theta_B \phi_B} \tag{16b}$$

where $\theta_B$, $\phi_B$ are half power beamwidths, in degrees, measured in the two principal planes.

Array antenna radiation pattern,

$$G(\theta) = G_c(\theta) G_a(\theta) \tag{17}$$

where:

$G_c(\theta)$ = element factor;

$G_a(\theta)$ = array factor.

Half power beamwidth,

$$\theta_B = \frac{0.886\,\lambda}{N_d \cos \theta_o} \tag{18}$$

where:

$\lambda$ = wavelength, m;

$N$ = number of error elements;

$d$ = distance that the array elements are spaced, m;

$\theta_o$ = beam position off broadside.

Phase shift between adjacent elements of the array,

$$\phi = 2\pi(d/\lambda)\sin\theta_o \tag{19}$$

where d, $\lambda$, $\theta_o$ are defined as in Eq. (18).

Distance between radar and target along the line of sight,

$$d_o = \sqrt{2kah_1} + \sqrt{2kah_2} \tag{20}$$

where:

$a$ = earth's radius;

$k$ = factor account for refraction due to a uniform gradient of refraction,;

$h_1, h_2$ = heights of radar antenna and target, respectively.

Power received from the clutter,

$$c = \frac{P_t G A_e \sigma_c}{(4\pi)^2 R^4} \tag{21}$$

where:

$P_t$ = transmitter power;

$G$ = antenna gain;

$A_e$ = antenna effective aperture;

$R$ = range

$\sigma_c$ = clutter cross section.

Signal power returned from a target with cross section $\sigma_t$,

$$S = \frac{P_t G A_e \sigma_t}{(4\pi)^2 R^4} \tag{22}$$

Range of a 0th radar,

$$R^4 = \frac{P_{av} G_t G_r \lambda^2 \sigma F_p^2 T_c}{(4\pi)^3 N_u (S/N) L_s} \tag{23}$$

where: $R$ = range;

$P_{av}$ = average power;

$G_t$ = transmitting antenna gain;

$G_r$ = receiving antenna gain;

$\lambda$ = wavelength;

$\sigma$ = target cross section;

$F_p$ = factor to account for the one-way propagation effects;

$T_c$ = coherent processing gain;

$N_o$ = receiver noise power per unit bandwidth;

$(S/N)$ = signal-to-noise (power) ratio;

$L_s$ = system losses.

Cross over range,

$$R_{ss}^2 = \frac{P_{tr}}{P_{ts}} \frac{G_r}{G_j} \frac{\sigma}{4\pi} \frac{B_j}{B_r} \frac{J}{S} \tag{24}$$

where:

$P_{tr}$ = radar transmitter power;

$P_{tj}$ = jammer transmitter power;

$G_r$ = radar antenna gain;

$G_j$ = jammer antenna gain;

$\sigma$ = target cross section;

$B_j$ = jammer bandwidth;

$B_r$ = radar signal bandwidth;

J/S = jammer-to-radar signal (power) ratio at the output of the IF required to mask the radar signal.

Jammer noise power per hertz at the radar,

$$N_{oJ} = \frac{P_{tj} G_j A_e}{4 \pi R^2 B_j} \tag{25}$$

where:

$A_e$ = effective receiving aperture of the radar antenna;

R = range of jammer from radar;

$G_j$ = jammer antenna gain;

$B_j$ = jammer bandwidth;

$P_{tj}$ = jammer transmitter power.

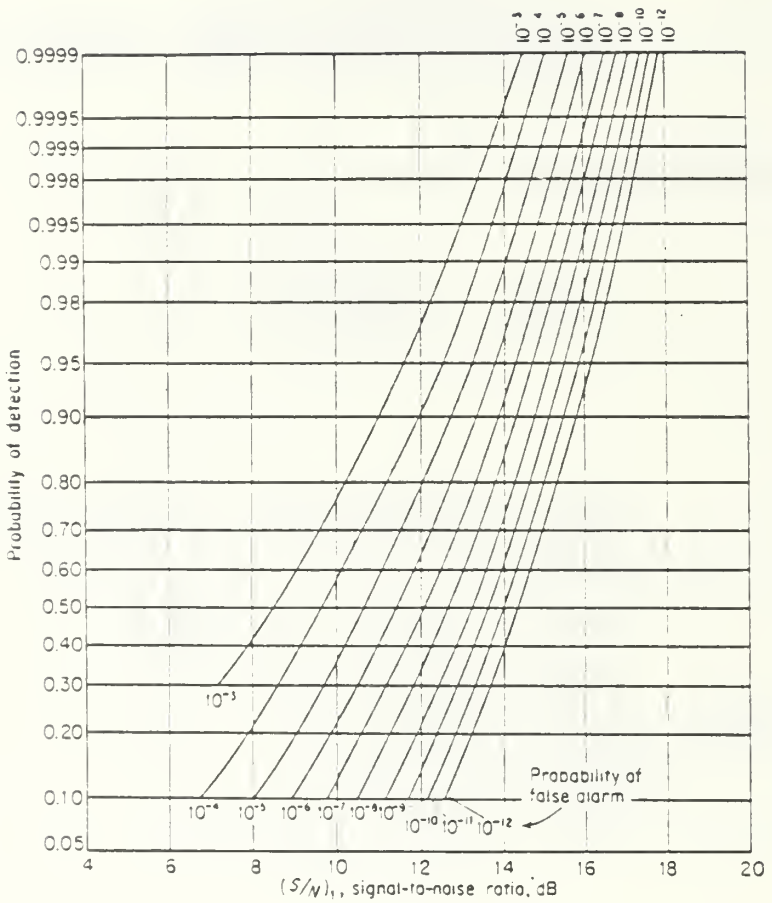



Figure 2.1. Probability of detection for a sine wave in noise as a function of the signal-to-noise (power) ratio and the probability of false alarm

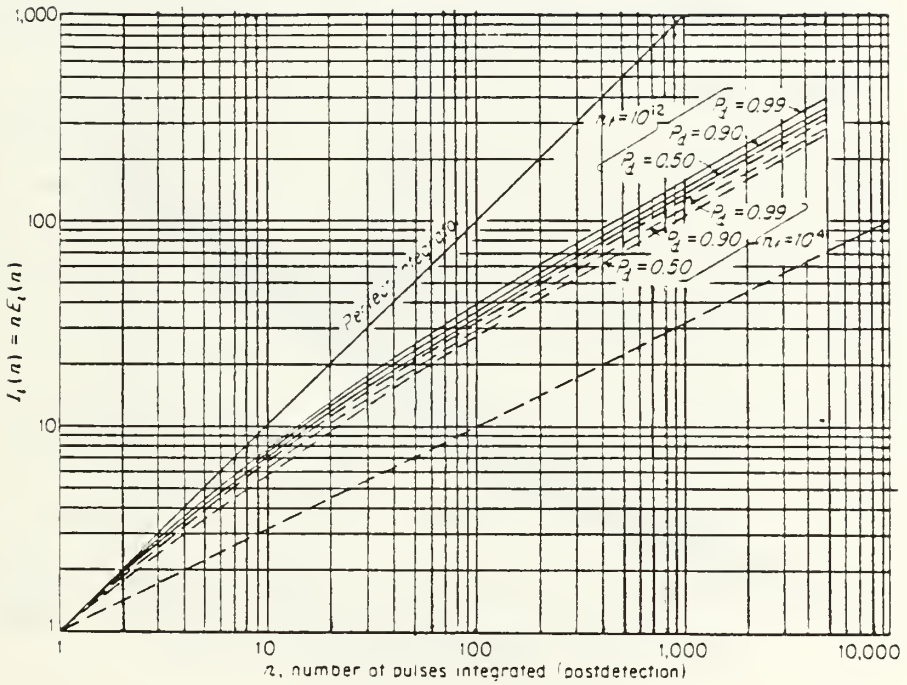



Figure 2.2. Integration-improvement factor, square law detector, $P_d$ = probability of detection, $n_f = T_{fa}$ = false alarm number, $T_{fa}$ = average time between false alarms, B = bandwidth

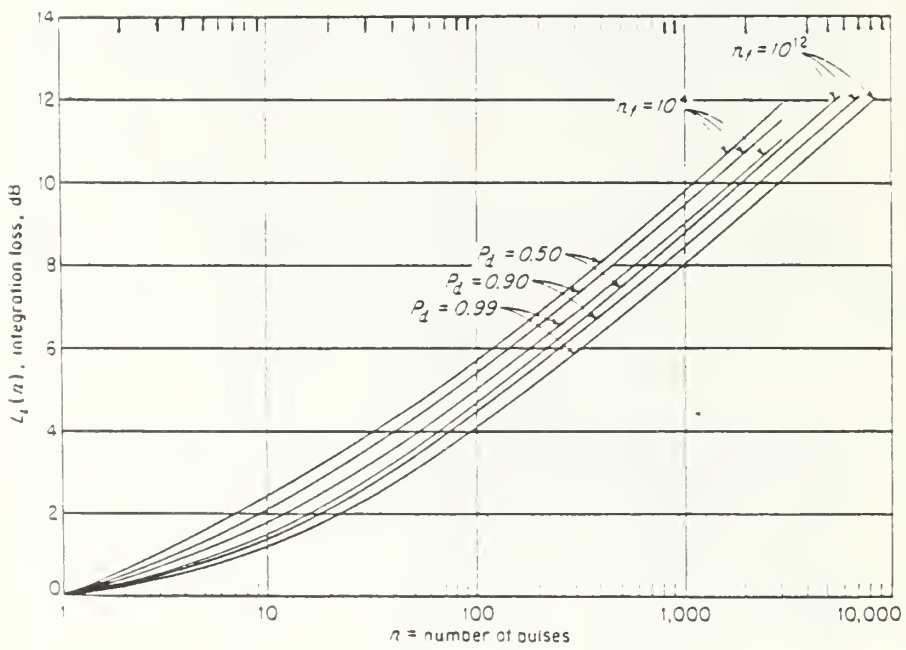



Figure 2.3. Integration loss as a function of n, the number of pulses integrated $P_d$, and $n_f$

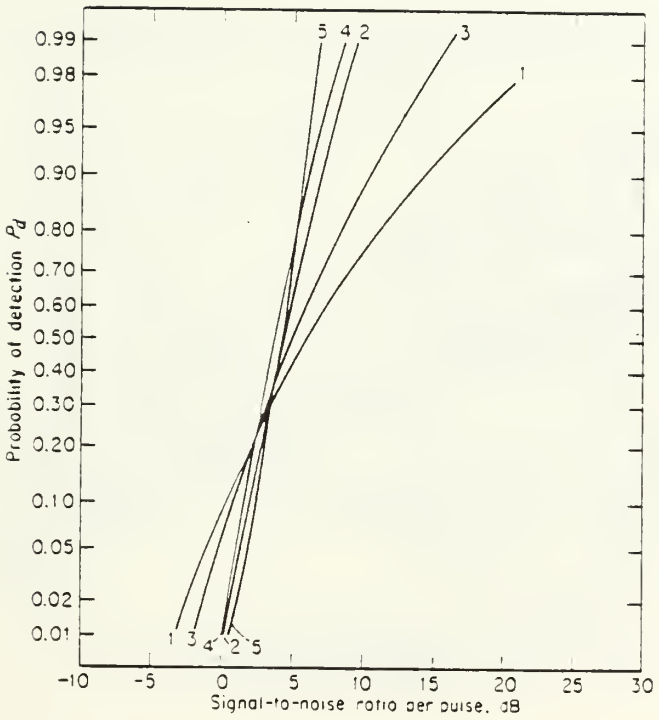



Figure 2.4. Comparison of detection probabilities for five different models of target fluctuation for n = 10 pulses integrated and false-alarm number $n_f = 10^8$

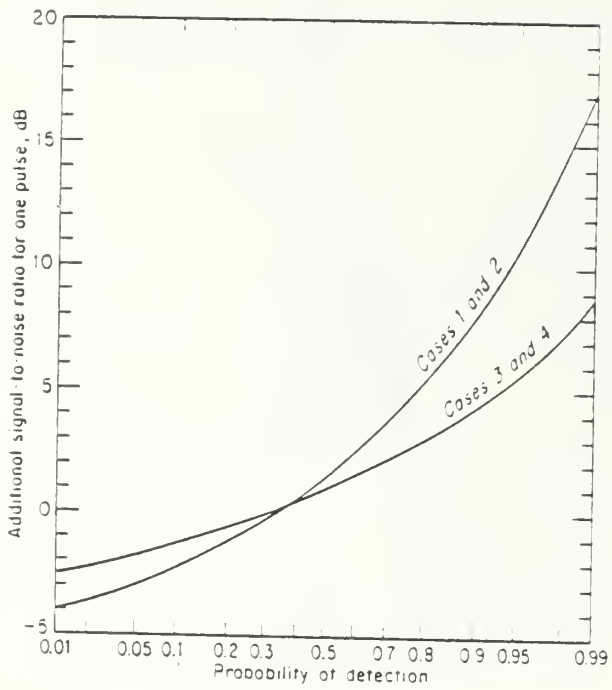



Figure 2.5. Additional signal-to-noise ratio required to achieve a particular probability of detection, when the target cross section fluctuates, as compared with a non fluctuating target; single hit, n = 1. (To be used in conjunction with Fig. 2.1 to find $(S/N)_1$)

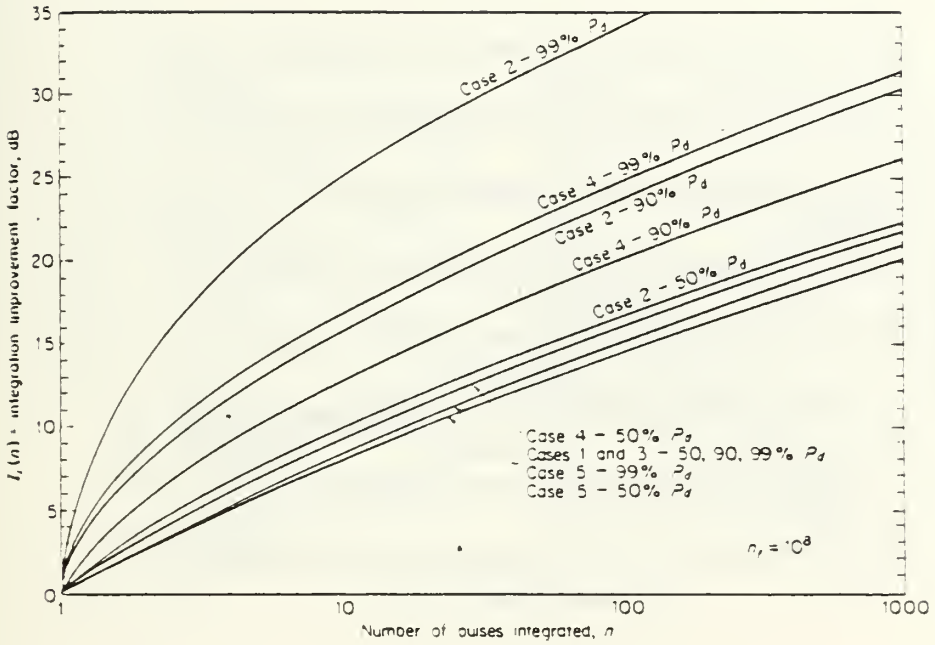



Figure 2.6. Integration-improvement factor as a function of the number of pulse integrated for the five types of target fluctuation considered

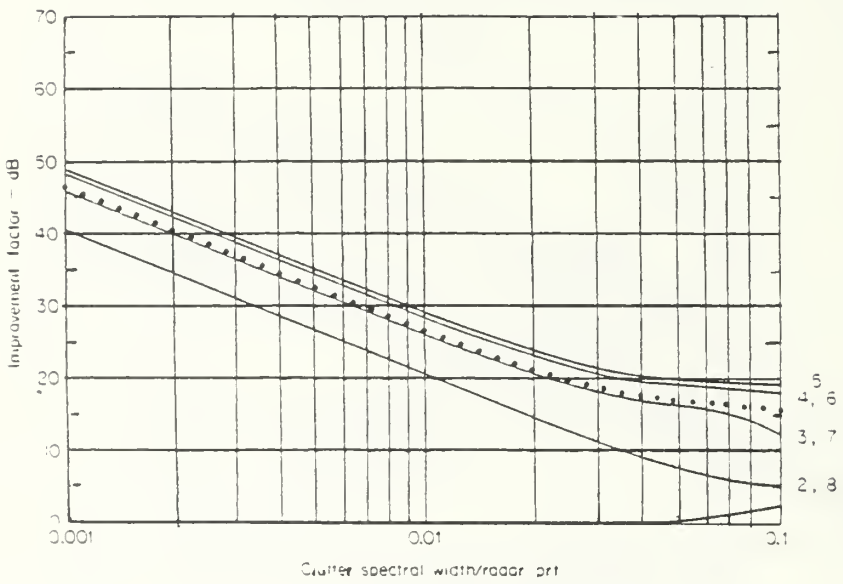



Figure 2.7. Improvement factor for each filter of an 8-pulse doppler filter bank with uniform weighting as a function of the clutter spectral width (standard deviation). The average improvement factor for all filters is indicated by the dotted curve

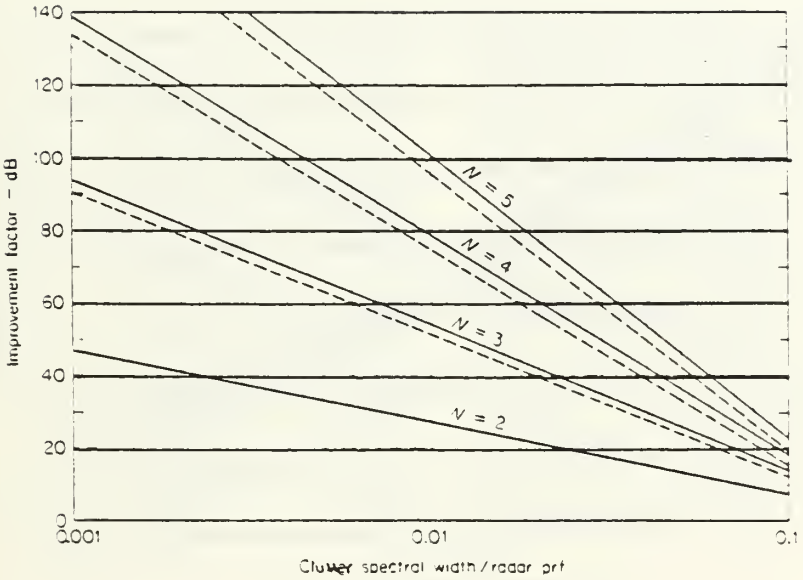



Figure 2.8. Improvement factor for a N-pulse canceler with optimum weights (solid curves) and binomial weights (dashed curves), as a function of the clutter spectral width

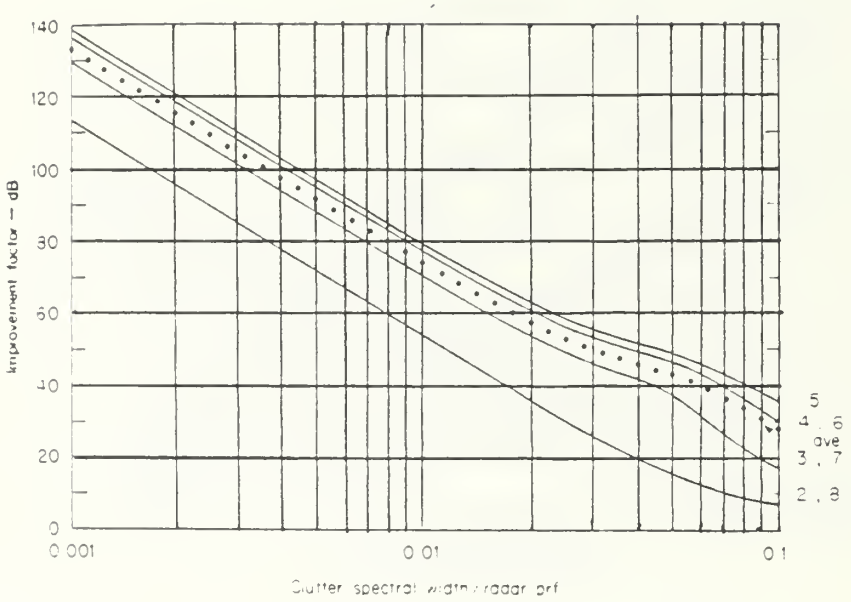



Figure 2.9. Improvement factor for a three-pulse (double canceler) MTI cascaded with an 8-pulse filter bank, or integrator, with uniform amplitude weights. The improvement for all filters is indicated by the dotted curve.

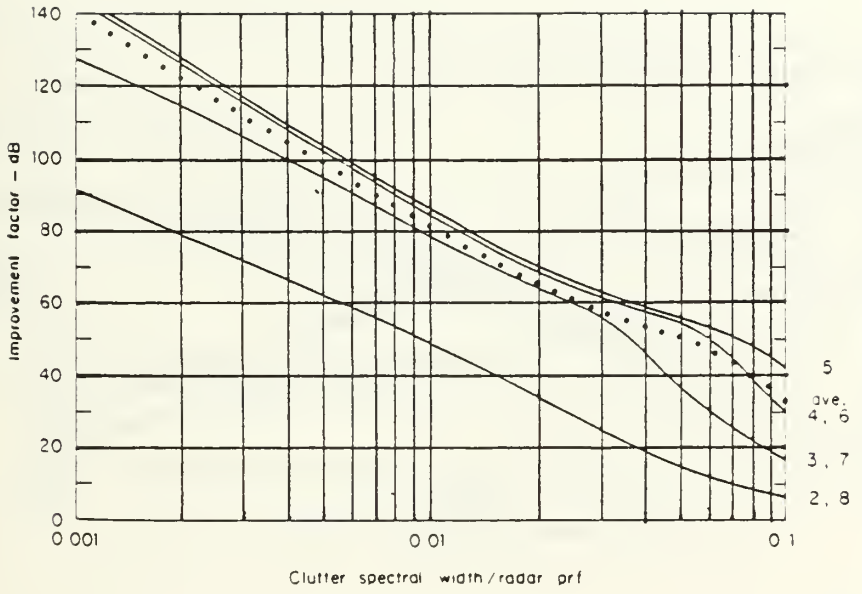



Figure 2.10. Improvement factor for a three-pulse (double canceler) MTI cascaded with an 8-pulse filter bank, or integrator, with 25-db Chebyshev weights. The improvement for all filters is indicated by the dotted curve

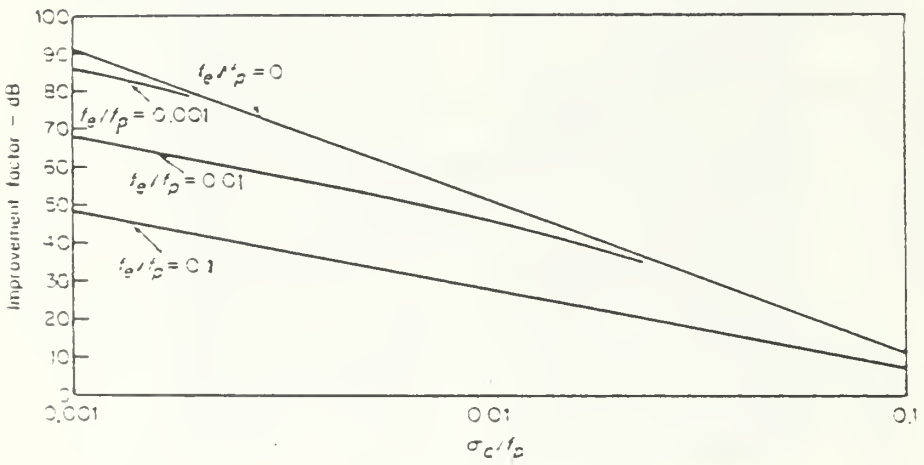



Figure 2.11. Effect of a nonzero clutter doppler frequency on the improvement factor of a three pulse canceler. $f_\theta$ = mean frequency of the clutter spectrum, $f_p$ = pulse repetition frequency

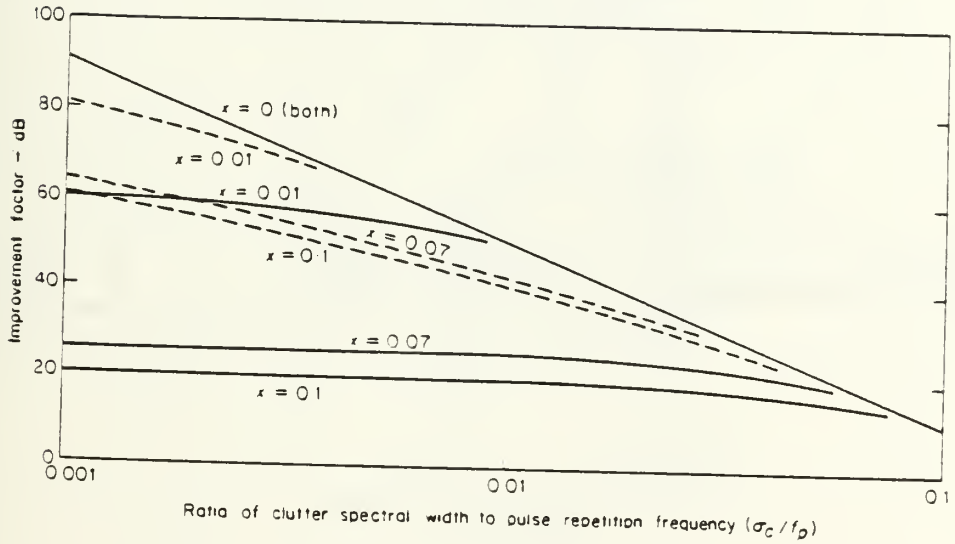



Figure 2.12. Improvement factor of a three-pulse canceler limited by platform motion (solid lines). Effect of the DPCA compensation (dashed lines). x is the fraction of the antenna aperture that the antenna is displaced per interpulse period. (x = 0 corresponds to no platform motion)

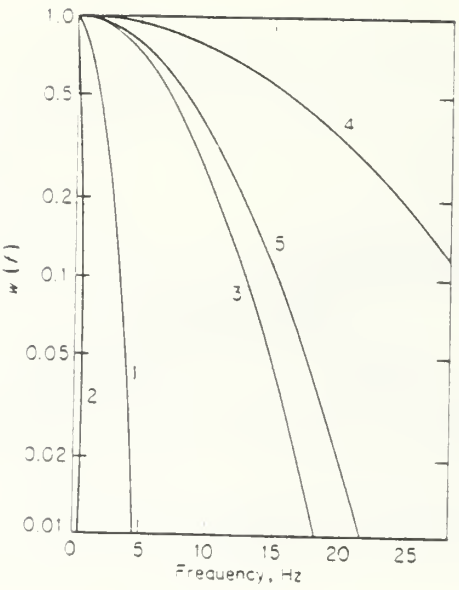



Figure 2.13. Power spectra of various clutter targets (1) Heavily wooded hills, 20 mi/h wind blowing ($a = 2.3 \times 10^{17}$); (2) sparsely wooded hills, calm day ($a = 3.9 \times 10^{19}$); (3) sea echo, windy day ($a = 1.41 \times 10^{16}$); (4) rain clouds ($a = 2.8 \times 10^{15}$); (5) chaff ($a = 1 \times 10^{16}$)

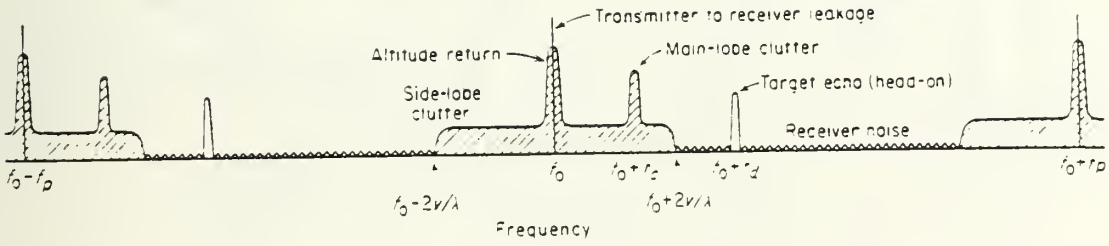



Figure 2.14. Portion of the received signal spectrum of the RF carrier frequency $f_o$, for a pulse-doppler AMTI radar

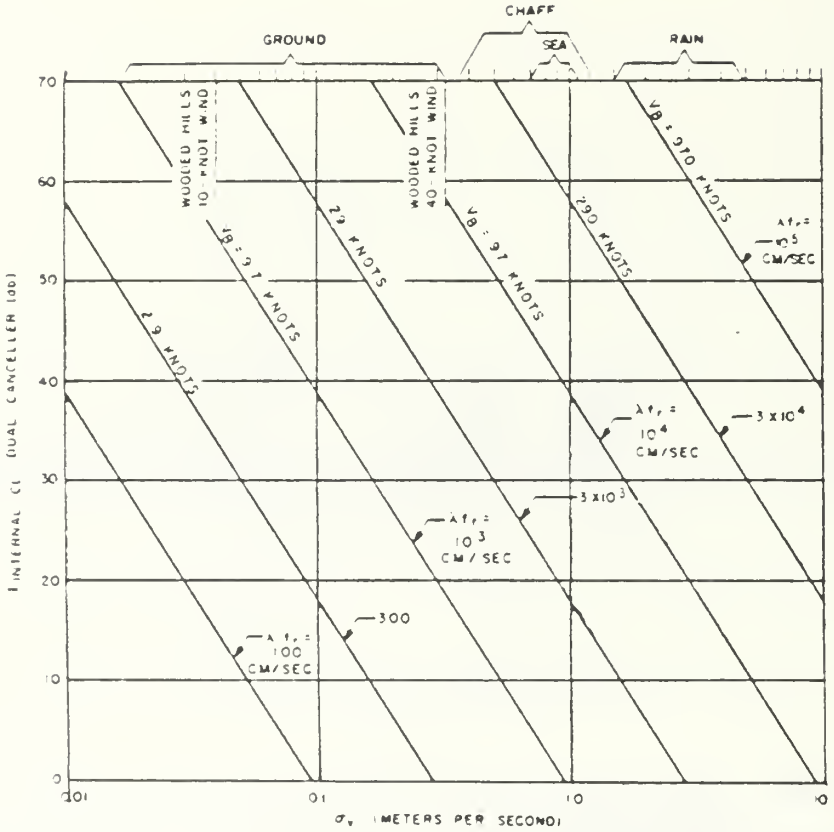



Figure 2.15. MTI improvement factor as a function of the RMS velocity spread of clutter for a two-delay canceler (no feedback)

Comparison of several types of spectral weighting functions:

TABLE 1

PROPERTIES OF WEIGHTING FUNCTION

| Weighting Function | Peak Sidelobe db | Loss db | Mainlobe width (relative) | Sidebbe decay function |
|---|---|---|---|---|
| Uniform | -13.2 | 0 | 1.0 | $1/t$ |
| $0.33+0.66\cos^2(\pi\ell/B)$ | -25.7 | 0.55 | 1.23 | $1/t$ |
| $\cos^2(\pi\ell/B)$ | -31.7 | 1.76 | 1.65 | $1/t^3$ |
| Taylor ($\bar{n} = 8$) | -40 | 1.14 | 1.41 | $1/t$ |
| Dolph-Chebyshev | -40 | .... | 1.35 | 1 |
| $0.08+0.92\cos^2(\pi\ell/B)$ (Hamming) | -42.8 | 1.34 | 1.50 | $1/t$ |

B = bandwidth

## III. RADAR PROBLEMS

### A. PROBLEM #1: DETECTION

Consider the design of a shipboard search radar. False alram rate is an annoying problem for the radar operator. Threshold detection is to be used. The bandwidth of the I-F amplifier is $B_{I-F}$ = 4 MHz. Calculate the threshold-to-rms noise voltage ( ) for a mean time between false alarms, $T_{fa}$, of:

a) 5 minutes

b) 50 minutes

c) 500 minutes

Solution

From Eq. (2.26) (Skolnik, pg. 25)

$$T_{fa} = \frac{1}{B_{IF}} \exp \frac{V_T^2}{2\psi_o} \tag{1}$$

where:

$T_{fa}$ = false alarm time;

$B_{IF}$ = bandwidth of the amplifier;

$V_T$ = threshold voltage;

$\psi_o^{1/2}$ = rms noise voltage.

From Eqn. (1),

$$V_t/\sqrt{\psi_o} = 2\{\ell n(T_{fa} \cdot B_{IF})\}^{1/2} \tag{2}$$

Substituting in Eq. (2) the values of $T_{fa}$ and $B_{IF}$ we find for:

Part a:

threshold-to-rms noise voltage: $V_T/\sqrt{\psi_o}$ = 6.466 (numeric) or 8.106 db.

Part b:

threshold-to-rms noise voltage: $V_t/\sqrt{\psi_o}$ = 6.813 (numeric) or 8.333 db.

Part c:

threshold-to-rms noise voltage: $V_t/\sqrt{\psi_o}$ = 7.143 (numeric) or 8.538 db.

B. PROBLEM #2: DETECTION LOSS

For a non-fading target, with probability of detection $P_d = 0.99$ and a false alarm number $n_f = 10^{12}$ with non-coherent integration, find the collapsing loss, if

a) n = 10 and m = 10

b) n = 10 and m = 90

Solution

From Figure 2.8(a) (Skolnik, pg. 31) we can find the integration loss for $L_i(m+n)$ and $L_i(n)$, since the probability of detection $P_d$ and the false alarm number $n_f$ are known.

$$L_i(m+n) = L_i(10+10) = L_i(20) = 1.9 \text{ db}$$

$$L_i(n) = L_i(10) = 1.3 \text{ db}$$

From Eq. (2.52) (Skolnik, Pg. 59),

$$L_i(m,n) = \frac{L_i(m+n)}{L_i(n)} \qquad (3)$$

where:

$L_i(m,n)$ = collapsing loss;

$L_i(m+n)$ = integration loss for m+n pulses;

$L_i(n)$ = integration loss for n pulses.

Substituting in Eq. (3), the values of $L_i(20)$ and $L_i(10)$, we get the collapsing loss,

$$L_i(10,10) = 1.9 - 1.3 = 0.6 \text{ db or } 1.14815 \text{ (numeric)}$$

Part b:

From the same Figure 2.8(a), we can find that

$$L_i(m+n) = L_i(90+10) = L_i(100) = 4.1 \text{ db}$$

$$L_i(n) = L_i(10) = 1.3 \text{ db}$$

Substituting in Eq. (3) the values of $L_i(100)$ and $L_i(10)$ we get the collapsing loss

$$L_i(90,10) = 4.1 - 1.3 = 2.8 \text{ db or } 1.905 \text{ numeric.}$$

C. PROBLEM #3: MAXIMUM RANGE

A pulse radar uses a magnetron with a peak power $P_t$ = 1.0 Mw, a pulse width $\tau$ = 1.0 μs, and a pulse repetition frequency $f_p$ = 250 Hz. It operates at $\lambda$ = 10 cm, and the effective antenna aperture $A_e$ = 200 $m^2$. Ten pulses are integrated after

detection. The receiver noise figure $F_n$ = 10 db and it has a noise bandwidth $B_n$ = 1.0 MHz. Plumbing losses $L_p$ = 3.0 db and the beam shape $L_{bs}$ = 2.0 db. Exponential (continuous) integration is used, resulting in a reduction by a factor of 0.85 in the integration efficiency. Threshold detection is used with a false alarm probability $P_{fa} = 10^{-9}$.

a) Find the maximum unambiguous range

b) Find the maximum range for a detection probability $P_d$ = 0.99 on a target with $\sigma_{av}$ = 1 $m^2$ average cross section, if fading follows the Rayleigh power distribution law and occurs from pulse to pulse (case 2). Assume there is no atmospheric attenuation.

Solution:

From Eq. 1.2 (Skolnik, Pg. 3) the maximum unambiguous range is

$$R_{unamb} = \frac{c}{2f_p} \tag{4}$$

where:

$c$ = velocity of the light = $3 \times 10^8$, m/s;

$f_p$ = pulse repetition frequency, Hz;

so,

$$R_{unamb} = \frac{3 \times 10^8}{2 \times 250} = 6 \times 10^5 \text{ m} = 600 \text{ km.}$$

Part b:

From Eq. 2.54 (Skolnik, Pg. 62) the maximum radar range is given by the formula,

$$R_{max}^4 = \frac{P_{av} G A \rho_a \sigma n E_i(n)}{(4\pi)^2 k T_o F_n (B_n \tau) f_p (S/N)_1 L_s} \quad (5)$$

where:

$R_{max}$ = maximum radar range, m;

$G$ = antenna gain;

$A$ = antenna aperture, $m^2$

$\rho_a$ = antenna efficiency;

$n$ = number of hits integrated;

$E_i(n)$ = integration efficiency (less than unity);

$L_s$ = system losses (greater than unity) not included in other parameters;

$\sigma$ = radar cross section of target, $m^2$;

$F_n$ = noise figure;

$k$ = Boltzmann's constant = $1.38 \times 10^{-23}$ J/deg.;

$T_o$ = standard temperature = 290 k;

$B_n$ = receiver bandwidth, Hz;

$\tau$ = pulse width, seconds;

$f_p$ = pulse repetition frequency, Hz;

$(S/N)_1$ = signal-to-noise ratio required at receiver output (based on signle-hit detection).

From Eq. 2.43 (Skolnik, Pg. 52),

$$P_{av} = P_t \tau f_p \quad (6)$$

where:

$P_{av}$ = the average radar power, w;

$P_t$ = the average transmitter power, w;

$\tau$ = pulse width, s;

$f_p$ = pulse repetition frequency, Hz.

From Eqn. 7.9 (Skolnik, Pg. 227),

$$G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi \rho_a A}{\lambda^2} \tag{7a}$$

$$A_e = A\rho_a \tag{7b}$$

where:

$A_e$ = effective area;

$A$ = physical area of antenna;

$\rho_a$ = antenna aperture efficiency;

$\lambda$ = wavelength.

The total system losses are:

$$L_s = L_p + L_{bs} \tag{8}$$

where:

$L_s$ = system losses, db;

$L_p$ = plumbing losses, db;

$L_{bs}$ = beam shape, db.

So,

$$L_s = 3 + 2 = 5 \text{ db} = 3.1622$$

From Fig. 2.7 (Skolnik, Pg. 28), the signal-to-noise ratio $(S/N)_1 \doteq 15.9$ db, for probability of detection $P_d = 0.99$

and false alarm probability $P_{fa} = 10^{-9}$. From Fig. 2.23 (Skolnik, Pg. 48) the additional signal-to-noise ratio $(S/N)_{ladd} \doteq 17.2$ db for case 2 and $P_d = 0.99$. So,

$$(S/N)_{lTOT} = (S/N)_l + (S/N)_{ladd} \tag{9}$$

so $(S/N)_{lTOT} = 15.9 + 17.2 = 33.1$ db or 2041 (numeric). From Fig. 2.24 (Skolnik, Pg. 49) the integration improvement factor $I_i(n) = 25$ db = 316.22 (numeric),

$$I_i(n) = nE_i(n) \tag{10}$$

where:

$I_i(n)$ = integration improvement factor, db;
$E_i(n)$ = integration efficiency;
$n$ = number of hits integrated.

From Eq. (10),

$$E_i(n) = \frac{I_i(n)}{n} \tag{10a}$$

and because we have a reduction by 0.85 in the integration efficiency, Eq. (10a) becomes

$$E_i(n) = \frac{I_i(n)}{n} \times 0.85 \tag{10b}$$

so

$$E_i(n) = \frac{316.22}{10} \times 0.85 = 26.537$$

Now substituting Eqs. (6), (7a), (7b), (8), (9), (10) in Eq. (5), and simplifying, we get

$$R_{max} = \frac{P_t A_e^2 \sigma n E_i(n) \ 0.85}{(4\pi) \ k \ t_o \ F_n \ B_n \ \lambda^2 (S/N)_{1TOT} \ L_s}^{1/4} \qquad (11)$$

$$= \frac{(1 \times 10^6) \times (200)^2 \times 1 \times 26.537 \times 10}{(4\pi) \times 1.38 \times 10^{-23} \times 290 \times 10 \times (1 \times 10^6) \times (0.1)^2 \times 2041.73 \times 3.1622}$$

$$= 758.57 \text{ km}$$

D. PROBLEM #4: FM-RANGING, DOPPLER

A CW FM radar operates at $f_o$ = 10.5 GHz. The frequency increases at a rate $\dot{f}_o$ = 2 GHz/sec for T = 990 microseconds, and then returns to its original value in $T_r$ = 10 microseconds.

a) Calculate the frequency shift of the echo from a target at a range R = 5000 yards

b) Calculate the range error due to doppler shift if the closing rate of the radar and target $U_r$ = 25 ft/sec.

Solution:

From Eq. 3.10 (Skolnik, Pg. 82)

$$f_r = \dot{f}_o T \qquad (11a)$$

$$f_r = \dot{f}_o \ 2R/C \qquad (11b)$$

where:

$f_r$ = the beat frequency due to the target range;

$\dot{f}_o$ = rate that the frequency changes;

T = rate that takes an echo signal to return;

$R$ = target range;

$C$ = speed of light = $3 \times 10^8$ w/d.

So, from Eq. (11b) the frequency shift is:

$$f_r = \frac{2 \times 10^9 \times 2 \times 5.000 \times 0.914}{3 \times 10^8} = 60.933 \text{ kHz}$$

Part b:

From Eq. 3.2(a) (Skolnik, Pg. 69)

$$f_d = \frac{2U_r}{\lambda} \tag{12}$$

where:

$f_d$ = doppler frequency shift, Hz;

$U_r$ = relative velocity, m/s;

$\lambda$ = wavelength of radiated energy, m.

So, from Eq. (12),

$$f_d = \frac{2 \times 25 \times 0.305 \times 10.5 \times 10^9}{3 \times 10^8} = 533.75 \text{ Hz}$$

The range error is given by the

$$\Delta R = \frac{R \times f_d}{f_r} \tag{13}$$

So,

$$\Delta R = \frac{5000 \times 533.75}{60.933 \times 10^3} = 43.798 \text{ yards} = 40.03125 \text{ m}$$

or 0.4% m = 0.4379% yards.

E. PROBLEM #5: BLIND SPOTS IN DOPPLER

A 9 GHz radar operates with a pulse width $\tau$ = 1 μs and a PRF $f_p$ = 1000 Hz.

a) What is the first blind speed?

b) A jet aircraft is flying $U_{air}$ = 600 knots. If the above radar detects the aircraft, will there be a doppler ambiguity? Explain.

Solution:

From Eq. 4.8 (Skolnik, Pg. 108)

$$U_{lbl} = \frac{\lambda f_p}{2} \tag{14}$$

where:

$U_{lbl}$ = the first bline speed, m/s;

$\lambda$ = wavelength, Hz;

$f_p$ = pulse repetition frequency, Hz.

So, the first blind speed is

$$U_{lbl} = \frac{c}{f}\frac{f_p}{2} = \frac{3 \times 10^8 \times 1000}{2 \times 9 \times 10^9} = 16.66 \text{ m/s} = 32.36 \text{ knots}$$

Part b:

Since $U_{air}$ = 600 knots > $U_{lb}$ = 32.36 knots, there will be a doppler ambiguity.

F. PROBLEM #6: MTI

A 1000 Hz PRF radar with a clutter spectral width $\sigma_c$ = 10 Hz, uses a 3 pulse delay line canceller, with optimal weighting. What is the MTI improvement factor in db?

Solution:

$$\frac{\text{Clutter spectral width}}{\text{radar PRF}} = \frac{\sigma_c}{f_p} = \frac{10}{1000} = 0.01 \qquad (15)$$

From Figure 4.25 (Skolnik, Pg. 124) the MTI improvement factor I = 55 db, for a 3-pulse delay-line canceller, with optimum weights, and $\sigma_c/f_p = 0.01$.

G. PROBLEM #7: POWER, NOISE POWER, S/N

The following data for a pulse radar is available:

Peak power $p_p$ = 200 kw;

Pulse repetition rate $r_p$ = 300 Hz;

Pulse width $\tau$ = 60 microsec;

False alarm time $T_{fa}$ = 2.2 hrs;

Receiver noise figure $r_n$ = 65 db;

Transmitter frequency, $f_o$ = 400 MHz;

IF: $F_{IF}$ = 120 MHz;

IF bandwidth: $B_{IF}$ = 1.25 MHz;

Antenna power gain: $G_a$ = 21 db;

Minimum detectable signal MDS = -115 dbm.

a) What is the average output power?

b) What is the noise power? How does it compare to the minimum detectable signal? What is the rms threshold power to noise ratio if no pulse integration is performed?

c) For a target of $\sigma$ = 1 sq. m cross section which fluctuates from pulse to pulse according to the one-plus-Rayleigh power distribution, what is the minimum signal to noise ratio required to achieve a probability of detection if n = 30 pulses are integrated after post-detection?

d) Use $(S/N)_{min}$ = 4 db as the answer to the above problem instead of the solution you obtained. Assume the total system losss $L_s$ = 1 db. What is the maximum range of the radar for the detection of the target described above with probability of detection $P_d$ = 0.5?

e) If the radar has a minimum range R = 10.5 km, what is its approximate TR recovery time?

Solution:

Part a:

From Eq. 2.43 (Skolnik, Pg. 52) the average output power may be written as:

$$P_{av} = P_p \times \tau \times f_p \qquad (16)$$

where:

$P_p$ = peak power, w;

$\tau$ = width of the transmitted rectangular pulses, sec.;

$f_p$ = pulse repetition rate.

So,

$$P_{av} = (200 \times 10^3) \times (60 \times 10^{-6}) \times 300 = 3.6 \text{ kw}$$

Part b:

From Eq. 2.2 (Skolnik, Pg. 18) the noise power $N_n$ generated by a receive of bandwidth $B_{IF}$ at a temperature T (degrees Kelvin) is equal to

$$N_n = k\ T\ B_{IF} \qquad (17)$$

where:

$k$ = Boltzmann's constant = $1.38 \times 10^{-23}$ J/deg.;

$T$ = 290° Kelvin (room temperature).

So,

$$N_n = (1.38 \times 10^{-23}) \times 290 \times (1.25 \times 10^6) = 5 \times 10^{-15} \text{ watts}$$

$$= -113 \text{ dbm.}$$

The noise power $N_n$ = -113 dbm > MDS = -115 dbm.

From Eq. 2.26 (Skolnik, Pg. 25) the threshold power to noise ratio is equal to

$$\frac{V_T^2}{2\psi_o} = \ell n(T_{fa} \times B_{IF}) \qquad (18)$$

where:

$T_{fa}$ = false alarm time;

$B_{IF}$ = bandwidth of the amplifier;

$V_T$ = threshold voltage,

$\psi_o^{1/2}$ = rms noise voltage.

So,

$$\frac{V_T^2}{2\psi_o} = \ell n(22 \times 3600 \times 1.25 \times 10^6) = \ell n(9.9 \times 10^9) = 13.6 \text{ db}$$

Part c:

From Figure 2.7 (Skolnik, Pg. 28), for probability of detection $P_d = 0.5$ and false alarm probability $P_{fa} = \frac{1}{T_{fa} \times B_{IF}} = \frac{1}{2.2 \times 3600 \times 1.25 \times 10^6} \doteq 10^{-10}$, the signal-to-noise ratio $(S/N)_1 \doteq 13.6$ db.

From Figure 2.23 (Skolnik, Pg. 48) the additional signal-to-noise ratio for one pulse is $(S/N)_{10dd} = 1.0$ db. So,

$$(S/N)_{1TOT} = (S/N)_1 + (S/N)_{10dd} = 13.6 + 1.0 = 14.6 \text{ db}$$

(case 4).

From Figure 2.24 (Skolnik, Pg. 49) for $P_d = 0.5$ and for $n = 30$ integrated pulses the integration improvement factor $I_i(n) = 11.4$ db.

The minimum signal to noise ratio $(S/N)_{30} = \frac{(S/N)_{1TOT}}{I_i(n)} = 14.6$ (db) - 11.4 (db) = 3.2 db.

Part d:

The basic radar range equation may be written as:

$$R_{max}^4 = \frac{P_t G_a^2 \lambda^2 \sigma}{(4\pi)^3 k T B_{IF} F_n (S/N)_{30} L_s} \qquad (19)$$

A simple way to handle the mathematics is to convert all of the factors to db and then add and subtract.

Numerator

| | | |
|---|---|---|
| $P_t = 200 \times 10^3$ watts | = | +53.0 dbw |
| $G_a^2 = 2 \times 21$ db | = | +42.0 db |

$\lambda^2 = \left(\frac{3 \times 10^8}{400 \times 10^6}\right)^2 = 0.5625 =$ -12.5 db (negative because of characteristic)

$\sigma$ = 1 sq. m = + 0.0 db

$\Sigma$ N = +92.5 dbw

Denominator

$(4\pi)^3 = 3 \times 10.97$ db = + 32.9 db

$kT_o = 4 \times 10^{-21}$ W/Hz = - 204 dbw

$B_{IF} = 1.25 \times 10^6$ Hz = + 60.9 db

$F_n$ = 6.5 db = + 6.5 db

$(S/N)_{30}$ = 4 db = + 4.0 db

$L_s$ = 1 db = + 1.0 db

$\Sigma$ D = -98.7 dbw

$$R_{max} = \frac{1}{4}[\Sigma N - \Sigma D] = \frac{1}{4}[92.5 - (-987)] = 47.8 \text{ db}$$

$$= 60.25 \text{ km}$$

Part e:

The recovery time is equal to

$$T_R = \frac{2R}{c} - \tau = \frac{2 \times 10.5 \times 10^3}{3 \times 10^8} - 60 \times 10^6 = 10 \ \mu\text{sec.}$$

H. PROBLEM #8: MTI-CHAFF DISCRIMINATOR

A 6 GHz, 1000 Hz PRF MTI radar uses a double delay line canceller against chaff. What is its improvement factor in db?

Solution:

The improvement factor, for a double canceller is given in Eq. 4.26 (Skolnik, Pg. 133) and is equal to:

$$I_{2c} = \frac{a^2 f_p^4}{2\pi^4 f_o^2} \tag{20}$$

where:

$f_p$ = the pulse repetition frequency, Hz;

$f_o$ = the operating frequency, Hz;

$\pi$ = 3.14159

a = parameter dependent upon clutter.

The parameter $a = c^2/8\sigma_u^2$, where $c = 3 \times 10^8$ m/s, $\sigma_u$ = the rms velocity spread.

From Figure 13 (Skolnik, Pg. 16-17), the rms velocity spread varies from $\sigma_{U1} = 0.4$ m/s to $\sigma_{U2} = 1$ m/s, so

$$a_1 = \frac{c^2}{8\ \sigma_{U1}^2} = \frac{(3 \times 10^8)^2}{8 \times (0.4)^2} \doteq 7 \times 10^{16} \quad \text{and}$$

$$a_2 = \frac{c^2}{8\ \sigma_{U2}^2} = \frac{(3 \times 10^8)^2}{8 \times (1)^2} = 1.125 \times 10^{16}$$

So, the improvement factor for $a_1 = 7 \times 10^{16}$ is

$$I_{2c_1} = \frac{a_1^2 f_p^4}{2\pi^4 f_o^4} = \frac{(7 \times 10^{16})^2 \times (1000)^4}{2 \times \pi^4 \times (6 \times 10^9)^4}$$

$$= 1.94 \times 10^4 = 43 \text{ db}$$

and for $a_2 = 1.125 \times 10^6$, is

$$I_{2c_2} = \frac{(1.125 \times 10^{16})^2 \times (1000)^4}{2 \times \pi^4 \times (6 \times 10^9)^4} \doteq 501.18 = 27 \text{ db}$$

So, the improvement factor is from 43 db to 27 db.

I. PROBLEM #9: MTI-CHAFF-CLUTTER DISCRIMINATOR

Find the approximate reduction in the improvement factor, I, in db from the near ideal case, when the PRF $f_p = 300$ Hz, and the clutter doppler frequency is shifted on the average by $f_e = 30$ Hz and the rms clutter spread is approximately $_c = 3$ Hz. Assume a three pulse canceller.

Solution:

The $\frac{\text{rms clutter spread}}{\text{pulse repetition freq.}} = \frac{3}{300} = 0.01.$

Also, the

$$\frac{\text{mean freq. of the clutter spectrum}}{\text{pulse repetition freq.}} = \frac{30}{300} = 0.1$$

So, from Figure 4.34 (Skolnik, Pg. 141) the reduction of the improvement factor I = 24 db, for the near ideal case and for three pulse canceller.

J. PROBLEM #10: PHASED ARRAY-BW

The radar AN/FPS - 108 (COBRA DANE) is designed to scan up to 60 degrees off the antenna center axis. Assume the separation between two adjacent active array elements d = 210 cm and the radar is operating at $f_o$ = 1250 MHz. The diameter of the phase array antenna is D = 29 m.

a. What is the phase difference between two array elements along the horizontal direction if the antenna is steered along this direction, 10 degrees off center?

b. What is the beamwidth at this angle, if each array element has the same output power?

Solution:

Part a:

In order for the main beam of the radiation pattern to be positioned at an angle $\theta_o$ = 10°, the phase shift between adjacent elements of the array must be:

$$\phi = 2\pi \frac{d}{\lambda} \sin \theta_o \qquad (21)$$

where:

d = separation between two adjacent elements, m;

$\lambda$ = wavelength, m;

$\theta_o$ = degrees of center, of the position of the antenna.

So, the phase difference between two adjacent array elements

$$\phi = \frac{2 \times \pi \times 0.2 \times 1250 \times 10^6}{3 \times 10^8} \sin (10) = 52.09° \text{ (0.9 radians)}$$

Part b:

From Eq. 8.13 (Skolnik, Pg. 284) the half-power beamwdith is equal to:

$$\theta_B = \frac{0.866\ \lambda}{N\ d\ \cos\ \theta_o} \tag{22}$$

where:

$N$ = number of elements = 1;

$d$ = diameter of phase array antenna, m;

$\theta_o$ = degrees of center, of the position of the antenna;

$\lambda$ = wavelength, m.

So, the beamwidth at $\theta_o = 10°$, for the same output power of each array element is equal to:

$$\theta_B = \frac{0.866 \times 3 \times 10^8}{1 \times 29 \times 1250 \times 10^6 \times \cos\ 10} = 7.28 \times 10^{-3} \text{ radians}$$

$$= 0.417°$$

K. PROBLEM #11: PULSE RADAR-RMAX

Estimate the maximum range $R_{max}$ for the following pulse radar system:

| | |
|---|---|
| Antenna gain | $G_a = 21$ db; |
| Peak power | $P_t = 2$ MW; |
| Frequency | $f_o = 500$ MHz; |
| Ambient Temperature | $T_a = 62°F$ |
| Receiver bandwidth | $B_n = 1$ MHz; |

Target: Jet airliner with $\sigma = 5\ m^2$;

Receiver noise figure $F_n = 10$dbw;

Pulselength $\tau = 3$ microsec.;

$I_i(n) = nE_i(n) = 16.5$ db.

It is desired that the probability of detection be at least 90% and that the false alarm rate not exceed $10^{-11}$. Assume system losses are compatible with an airport surveillance radar system $L_s = 6$ db.

Solution:

The basic radar range equation may be written as:

$$R_{max}^4 = \frac{P_t\ G_m^2\ \lambda_o^2\ \sigma\ n\ E_i(n)}{(4\pi)^3\ k\ T_o\ B_n\ F_n (S/N)_1\ L_s} \qquad (23)$$

For the numerator:

| | | |
|---|---|---|
| $P_t = 2 \times 10^6$ watts | = | + 63 dbw |
| $G_o^2 = 2 \times 21$ dbi | = | + 42 db |
| $\lambda_o^2 = 0.36\ m^2$ | = | - 4.4 db |
| $\sigma = 5m^2$ | = | + 7.0 db |
| $nE_i(n) = 165$ db | = | + 16.5 db |
| $\Sigma$ N | = | + 124.1 dbw |

Denominator:

| | | |
|---|---|---|
| $(4\pi)^3 = 3 \times 10.97$ db | = | + 32 db |
| $kT_o = 4 \times 10^{-21}$ w/Hz | = | - 204 dbw |
| $B_n = 10^6$ Hz | = | + 60 db |
| $F_n = 10$ db | = | + 10 db |

$(S/N)_1$ = 15.4 db = + 15.4

$L_s$ = 6 db = + 6 db

$\Sigma D$ = -79.7 dbw

$$R_{max} = \frac{1}{4}[\Sigma N - \Sigma D] = \frac{1}{4}[124.1 - (-79.7)]$$

$$= \frac{203.8}{4} \text{ db} = 51 \text{ db}$$

$R_{max}$ = 122.5 km = 67.2 n. miles

## L. PROBLEM #12: TWS, PROBABILITY OF DETECTION

The AN/SPC-10 radar has the following operating parameters:

| | |
|---|---|
| Frequency | 5600 MHz |
| Power (peak) | 200 Lw |
| PRF | 625 Hz |
| Pulse width | 1.4 microsec. |
| Antenna scan rate | 16 Hz |
| Azimuth beamwidth (3 db) | 1.5 degrees |
| Antenna gain) | 33 db |
| Receiver noise bandwidth | 1 MHz |
| Receiver noise figure | 9.88 db |
| System losses (ahead of receiver) | 5 db |
| False alarm time | 2 days |
| Antenna noise temperature | 75 degrees K |
| PPI display + operator | |

(a) Calculate the number of hits/scan on a point target

(b) Determine the single pulse S/N in db required to achieve a detection probability of 0.95

(c) Determine the integration improvement factor

(d) Calculate the minimum detectable signal power in dbw

(e) Calculate the peak effective radiated power in dbw

(f) Calculate the effective area of the antenna in square meters

(g) Calculate the maximum free space detection range in km for a detection probability of 0.95 (with false alarm time = 2 days) on a 0 dbsw non-fluctuating point target

Solution:

Part a:

The number of pulses $n_B$ returned from a point target as the radar antenna scans through its beamwidth is

$$n_B = \frac{\theta_B}{2 \times 180} T_s f_p = \left(\frac{1.5}{360}\right) \times \left(\frac{60}{16}\right) \times (625)$$

$$= 9.77 \text{ hits/scan}$$

Part b:

The probability of false alarm is

$$P_{fa} = \frac{1}{T_{fa} B_{IF}} = \frac{1}{(2 \times 24 \times 3600 \text{ sec})(10^6 \text{ Hz})} = 58 \times 10^{-12}$$

From Figure 2.7 (Skolnik, Pg. 28) the signal-to-noise (power) ratio is $(S/N)_1 \doteq 16$ db for $P_d = 0.95$ and $P_{fa} = 58 \times 10^{-12}$

Part c:

From Figure 2.8(a) (Skolnik, Pg. 31), incoherent integration of 9 pulses gives $I_i(9) = 7 = 8.4$ db.

Part d:

The minimum detectable signal power is given as

$$\text{MDS} \quad k T_o B_n F_n = 138 \times 10^{-23} \times 290 \times 10^{6} \times 9.727 = -134.1 \text{ dbw}$$

Part e:

The peak effective radiated power is equal to:

$$P_{eff} = P_t G_t \tag{24}$$

where:

$P_t = 200 \times 10^3$ N = 53 db (transmitter power);

$G_t$ = 33 db (antenna gain).

So,

$$P_{eff} = 53 + 33 = 86 \text{ dbw.}$$

Part f:

The antenna effective area is equal to:

$$A_e = \frac{\lambda^2}{4\pi} \times G = \frac{(5.35 \times 10^{-2})^2}{4\pi} \times 2000$$

$$A_e = 0.456 \text{ m}^2 = -3.4 \text{ dbsm}$$

Part g:

The maximum radar range $R_{max}$ is equal to

$$R_{max} = \frac{P_t G_t A_e \sigma I_i(n)}{(4\pi)^2 k T_o \left(\frac{T_a + T_e}{T_o}\right) B_n (S/N)_1 L_s} \tag{25}$$

(1) $10 \log_{10}(4\pi)^2 = 22$ db

(2) $10 \log(\frac{T_a+T_e}{T_o}) = 10 \log_{10}(\frac{75+2530}{290}) = 9.53$ db

$$10 \log_{10}(R_{max}^4) = [86 \text{ dbw} - 3.4 \text{ db} + 0 \text{ dbsw} + 8.4 \text{ db}] - [22 \text{ db} - 204 + 9.53 + 60 + 16 + 5]$$

$$10 \log_{10} R_{max}^4 = 182.5 \text{ db}$$

$$R_{max} = 10^{4.56} = 36{,}307 \text{ m.}$$

So,

$R_{max}$ = 36.3 km ($P_d$ = 0.95 on 0 dbsw target)

M. PROBLEM #13: RECEIVER'S BANDWIDTH

A 10 GHz CW doppler radar of single sideband superheterodyne design, has the block diagram shown in Figure 3.4, pg. 75 of [Ref. 2]. The radar is to be designed to measure the speed of vehicles with RCS = 10 dBsm traveling at velocities up to 100 mi/hrs at ranges up to 1/2 miles. For reliable operation, a signal-to-noise ratio and 15 db is required at the output of the IF amplifier. The receiver noise figure is F = 7.25 db, plumbing loss is 2 db and $T_a$ = 300 degrees K. The transit and receive antennas have gains of 20 db each.

(a) Calculate the required receiver bandwidth

(b) Calculate the required receiver input signal power in dbm

(c) Calculate the one way free space loss in db for a target vehicle at a range of 1/2 miles

(d) Calculate the required transmitter output power

Solution

Part a:

$$U_{rmax} = 100 \text{ mi/hrs} = 44.72 \text{ m/sec}$$

$$f_d = \frac{2U_r f_o}{c} = \frac{2 \times 44.72 \times 10^{10} \text{ Hz}}{3 \times 10^8} = 2981 \text{ Hz}$$

$$B = 2f_d = 5962 \text{ Hz} \doteq 6\text{kHz}$$

Part b:

The receiver input signal power is equal to:

$$S_{in} = k(T_a + T_e)B(S/N)_{out} = k\,T_o\,(\frac{T_a+T_e}{T_o})B(S/N)_{out}$$

(1) $kT_o = -174$ dbw/Hz

(2) $\frac{T_a+T_e}{T_o} = \frac{300+1250}{290} = 5.34 = 7.28$ db

(3) $B = 6$ kHz $= 37.8$ db Hz

So,

$$S_{in} = -174 + 7.3 + 37.8 + 15 = -114 \text{ dbm.}$$

Allocate 1/2 of the plumbing loss to the receiver (1 db). Taking this into account, we would require

$$S_{in} = -113 \text{ dbm.}$$

Part c:

The one way free space loss is equal to

$$L_{bf} = 10 \log_{10}\left(\frac{4\pi R}{\lambda}\right)^2 = 10 \log_{10}\left(\frac{4\pi \times 805 \text{ m}}{0.03}\right)^2$$

$$L_{bf} = 110.6 \text{ db.}$$

Part d:

The required transmitter output power is:

$$P_t = P_{eff} - G_\sigma + (2L_{bf} - G_r - G_t) \qquad (26)$$

$$G_\sigma = 10 \log_{10} \frac{4\pi\sigma}{\lambda^2} = 41.4 \text{ db}$$

So from Eq. (26) we get

$$P_t = -113 \text{ dbm} - 41.4 \text{ db} + (2 \times 110.6 - 20 - 20)$$

$$P_t = 26.8 \text{ dbm}$$

If we assign the remaining 1 db of plumbing loss to the transmitter, we obtain

$$P_t = 27.8 \text{ dbm} = 603 \text{ m Watts.}$$

N. PROBLEM #14: BLIND SPEED--MTI

An 1 GHz MTI radar operates with a 4 period stagger T1:T2:T3:T4 = 25:30:27:31 and $T_{avg}$ = 0.001 sec. Calculate the periods T1 ~ T4 and the first blind speed in knots.

Solution:

$$\frac{T1 + T2 + T3 + T4}{4} = T_{avg} = 10^{-3} \text{ sec} \quad (27)$$

$$\frac{25}{T1} = \frac{30}{T2} = \frac{27}{T3} = \frac{31}{T4} \quad (28)$$

Substituting Eq. (28) in Eq. (27, we have

$$\frac{25}{25} T1 + \frac{30}{25} T1 + \frac{27}{25} T1 + \frac{31}{25} T1 = 10^{-3}$$

$$\frac{113\ T1}{100} = 10^{-3}$$

$$T1 = 884.96\ \mu\text{sec}$$

$$T2 = 1061.9\ \mu\text{sec}$$

$$T3 = 955.76\ \mu\text{sec}$$

$$T4 = 1097.35\ \mu\text{sec}$$

The first blind speed is (in knots)

$$U_1 = \frac{\lambda f_p}{1.02}\left(\frac{25 + 30 + 27 + 31)}{4}\right) = \frac{0.3 \times 10^3}{1.02} = 8309 \text{ knots}$$

O. PROBLEM #15: MTI WEIGHTS--DELAYS

An MTI radar operates at a frequency 1 GHz with PRF = k KHz.

(a) Calculate the first blind speed in knots

(b) Sketch a block diagram of a 4 pulse canceler for this radar. Show correct weights and delays

(c) Calculate the clutter rejection in db at a frequency of 25 Hz for the 4 pulse canceler

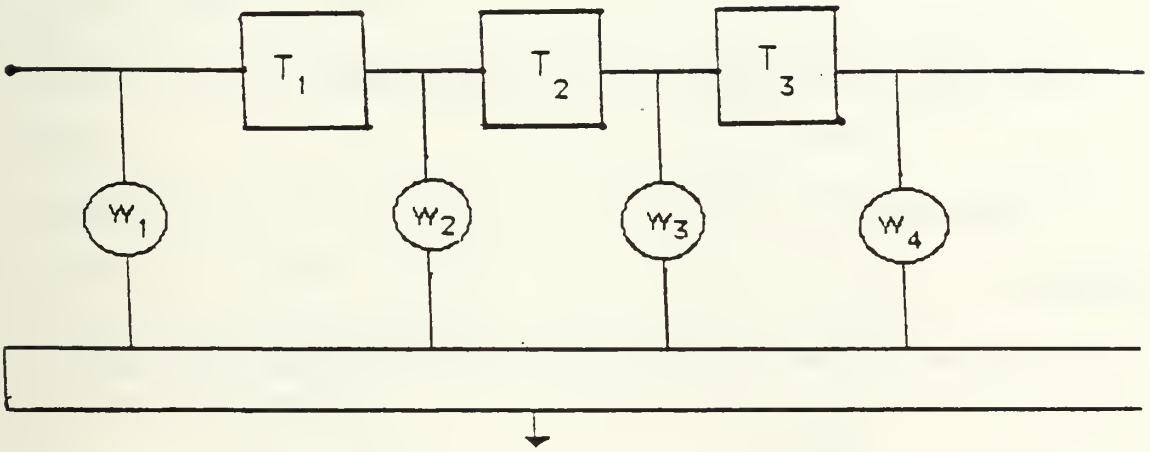
(d) If a target with a radial velocity of 200 knots is viewed with this radar, of what frequency will the bipolar video fluctuate?

Solution:

Part a:

$$U_{lbl} = \frac{\lambda f_p}{1.02} = \frac{3 \times 10^8 \times 1000}{10^9 \times 1.02} = 294.118 \text{ knots}$$

Part b:




$$T1 = T2 = T3 = 10^{-3} \text{ sec}$$

$$W_i = (-1)^{i-1} \frac{n!}{(n-i+1)^1 (i-1)!} \qquad i = 1,2,3,4 \quad n = 3$$

$$W1 = (-1)^0 \frac{3!}{3!0!} = 1$$

$$W2 = (-1)^1 \frac{3!}{2!1!} = -3$$

$$W3 = (-1)^2 \frac{3!}{1!2!} = 3$$

$$W4 = (-1)^3 = \frac{3!}{0!3!} = -1$$

Part c:

The relative response of the 4 pulse canceler is

$$\frac{H(f)}{H(f_p/2)} = \sin^3(\pi f T)$$

For $F_d$ = 25 Hz, the clutter rejection is

$$-20 \log_{10} \sin^3\left(\frac{\pi\ 25}{1000}\right) = -60 \log(.078)$$

$$R_{ejection} = 66.3 \text{ db}$$

Part d:

The bipolar video fluctuates at the doppler frequency

$$f_d = \frac{2U_r f_o}{c}$$

if $U_r$ is in knots,

$$f_d = \frac{1.03\ U_r}{\lambda} = \frac{1.03 \times 200}{.3}$$

$$f_d = 686.7 \text{ Hz}$$

## IV. EW PROBLEMS

### A. PROBLEM #1: DETECTION RANGE, UNAMBIGUOUS RANGE

A shipboard surface search radar has the following characteristics:

| | |
|---|---|
| Frequency | $f_o$ = 5600 MHz |
| Pulse width (long) | $T_\ell$ = 1.3 s |
| Pulse width (short) | $T_s$ = 0.25 s |
| Power output (peak) | $P_t$ = 200 kw |
| PRF | $f_p$ = 650 Hz |
| Bandwidth (long pulse) | $B_{re}$ = 1 MHz |
| Bandwidth (short pulse) | $B_{rs}$ = 5 MHz |
| Antenna scan frequency | $W_m$ = 16 RPM |
| Azimuth beamwidth | $\phi_B$ = 1.5° |
| Elevation beamwidth | $\theta_B$ = 14° |
| Antenna noise temperature | $T_u$ = 75 degrees k |
| False alarm probability | p = 1E-11 |
| Receiver noise figure | $F_n$ = 10 db |

The radar polarization is linear and deflections are made by an operator using a PPI display.

(a) Calcualte the maximum detection range for a 1 square meter non-fluctuating target, assuming that a detection probability $P_d$ = 0.95 is required. Neglect the effect of reflections from the sea surface

(b) Calcualte the maximum unambiguous range of the radar

(c) Calculate the range at which an aircraft with RCS = 10 dBsm will be detected with $P_d$ = 0.95. Assume the target is non-fluctuating and the radar is operating in the long pulse mode.

(d) Assume the radar antenna is 50 ft above the sea surface. For the case where the above aircraft is at the maximum detection range, calculate the minimum altitude at which the radar can see the target in a standard atmosphere

(e) Suppose that the radar signal is received by the aircraft above using a circular polarized antenna with 0 db gain. What is the single pulse power (in dbm) at the antenna output terminals, when the aircraft is at the maximum detection range? (Assume system loss $L_s$ = 3 db)

(f) Calculate the camouflage factor c, for this radar as given by Boyd et al., for the long pulse mode

(g) Suppose the aircraft above carries a noise jammer and transmits a 30 MHz, circular, polarized spot noise signal, covering the radar passband

Assuming a J/S = 5 db is required to work the target, calculate the Jammer output power required to achieve a 10 nuatical miles burnthrough range, when the radar is operated in the long pulse mode, if a 0 db gain jamming antenna is used.

Solution:

The maximum detection range is equal to

$$R_{max} = \left[\frac{P_t G_a A_e \sigma n E_i(n)}{(4\pi)^2 k (T_a+T_e) B_n (S/N)_{1max}}\right]^{1/4} \qquad (1)$$

where:

(1) $P_t$ = peak output power = $200 \times 10^3$

(2) $G_a$ = antenna gain = $\frac{41250}{\theta_B \phi_B} = \frac{41250}{14 \times 1.5}$

$\doteq$ 1964 = 32.9 db

(3) $A_e$ = antenna aperture = $\frac{\lambda^2 G_a}{4\pi} = \frac{c}{f_o} \frac{G_a}{4\pi}$

$$= \left(\frac{3 \times 10^8}{5600 \times 10^6}\right) \frac{1964}{4\pi} = 0.449 \text{ w}^2$$

(4) = radar cross section of target = 1 $m^2$

(5) Number of hits integrated = $\frac{\phi_B f_p T_s}{2\pi}$

$$= \frac{1.5}{360} \times (650 \text{ sec}^{-1}) \left(\frac{60}{16}\right) \text{sec} = 10 \text{ pulses}$$

(6) From Fig. 2.8(a) (Skolnik, Pg. 31), $nE_i(n) = I_1(10) = 7$

(7) $T_e$ = effective noise temperature = $(F_n - 1)T_o$

where $F_n$ = 10 db = 10 (numeric) and $T_o$ = 290°K, the standard temperature. So

$T_e = (10-1)290 = 2610°K.$

(8) $k(T_a + T_e)B_{re} = 1.38 \times 10^{-23}(75 + 2610)10^6$

$= 3.7 \ 10^{-14}$ watts (long pulse)

(9) $(S/N)_1$ = signal-to-noise ratio required at receiver output = 16 db = 39.8 (numeric) from Figure 2.7 (Skolnik, Pg. 28).

Using Eq. (1), we find that the maximum range is

$$R_{max\ell} = \frac{(2 \times 10^5 \text{ w})(1964)(0.449 \text{ w}^2)(1 \text{ w}^2)(7)}{(4\pi)^2 (3.7 \times 10^{-14} \text{ w}) 40}$$

$\doteq$ 47.9 km for the long pulse, and

and

$$R_{maxs} = R_{max\ell}\left(\frac{B_{re}}{B_{rs}}\right)^{1/4} = 47.9(l/s)^{1/4} = 32.08 \text{ km}$$

for the short pulse

So, for $\sigma = 1\ m^2$ and $P_d = 0.95$,

$$R_{max} = 47.9 \text{ km (long pulse)}$$

$$R_{max} = 32.08 \text{ km (short pulse)}$$

Part b:

The maximum unambiguous range $R_u$ is equal to

$$R_u = \frac{c}{2f_p} = \frac{3 \times 10^8}{2.650} = 230.77 \text{ km}$$

Part d:

For a $\sigma = 10\ m^2$ target, the detection range will be $10^{1/4} = 1.78$ times greater than that for a $\sigma = 1\ m^2$ target. So, the range at which an aircraft will be detected with $\sigma = 10\ m^2$, $P_d = 0.95$ will be

$$R = 1.78 \times R_{max} = 1.78 \times 47.96 = 85.36 \text{ km}$$

Part d:

The distance between radar and target along the line of sight is:

$$d_o = \sqrt{2h_1} + \sqrt{2h_2} \qquad (2)$$

where:

$h_1, h_2$ = heights of radar antenna and target, respectively;

$h$ = 50 ft;

$d_o$ = 85.3 km = 52.9 miles.

So, from Eq. (1),

$$\sqrt{2 \times 50} + \sqrt{2h_2} = 52.9 \quad \text{or} \quad h_2 = 923.77 \text{ ft},$$

is the minimum altitude at which the radar can see the target.

Part e:

The single pulse power at the antenna output terminal is

$$P_r = \frac{P_t G_a \lambda^2 G_r}{(4\pi) R^2 (4\pi) L_p} \tag{3}$$

where:

(1) $P_t$ = peak output power $P_t$ = 200 kw

(2) $G_a$ = antenna gain (calculated in part a)
= 32.9 db = 1964 (numeric)

(3) $G_r$ = receiver antenna gain = 0 db = 1 (numeric)

(4) $\lambda$ = wavelength = $c/f_o = \frac{3 \times 10^8}{5600 \times 10^6} = 0.0526$ m

(5) R = range at which an aircraft will be detected with RCS = 10 $m^2$ (calculated in part c) = 85.3 km

(6) $L_p$ = system losses = 3 db = 2 (numeric)

Using Eq. (3),

$$P_r = \frac{(2 \times 10^5 \text{ w})(1964)(0.0536)^2(1)}{(4\pi)^2(83.5 \times 10^3 \text{m})^2(2)} = -33.082 \text{ dbm}$$

Part f:

The camouflage factor c is

$$C = \frac{4}{(1 + \frac{1}{T_e B_{re}})^2} \times (\frac{f_p}{k})^{1/3} \quad (4)$$

where k = 1640 or 400, $T_e$ = Pulse width (long) = 1.3 μs

From Eq. (4), we get

$$C_1 = \frac{4}{1 + (\frac{1}{1.3 \times 10^{-6} \times 10^6})^2} \times (\frac{650}{1640})^{1/3} = 2.66 \text{ db}$$

$$C_2 = \frac{4}{1 + (\frac{1}{1.3 \times 10^{-6} \times 10^6})^2} \times (\frac{650}{400})^{1/3} = 4.7 \text{ db}$$

Part g:

The jammer output power $P_j$ is equal to:

$$P_j = \frac{P_t G_a \sigma g^2 L_p C}{4\pi R_B^2 B_{re} C_j} \quad (5)$$

where:

(1) $P_t$ = peak output power = $2 \times 10^5$ watts;

(2) $R_B$ = Burnthrough range inm = $18.5 \times 10^3$ m

(3) $\sigma$ = target radar cross section = 10 $m^2$

(4) $G_a$ = is the antenna gain = 1964 (numeric)

(5) $L_p$ = system losses = 2 (numeric)

(6) C = J/s = 15 db = 31.6 (numeric)

(7) $B_{re}$ = bandwidth for long pulse = $10^6$ Hz

(8) $B_r$ = Freq. the jammer transmits = $30 \times 10^6$ Hz

(9) $C_j$ = gain of the jamming antenna

(10) g = propagation factor (Assume = 1)

From Eq. (5), we get

$$P_j = \frac{(2 \times 10^5 \text{ w})(1964)(10 \text{ m}^2)(2)(31.6)}{4\pi(18.5 \times 10^3 \text{ m})^2(1 \text{ MHz})(1)} = 5.77 \text{ w/MHz}$$

or $P_j$ = .197 w/MHz for $B_r$ = 30 MHz

B. PROBLEM #2: ARRAY BROADSIDE POWER GAIN

The AN/SPS-85 is a multifunction phased array radar used for search and track of missiles and satellites. The operating frequency $f_o$ = 442 MHz and the transmit antenna is $d_1 \times d_2$ = 26.9 × 26.9 m rectangular array of N = 5184 elements. Assume that the illumination efficience of this array $p_i$ = 0.65 and that the feed and phase shifter losses amount to $p_R$ = 1.8 db for each element.

(a) Calculate the array broadside power gain

(b) Estimate the (pencil) beamwidth

(c) Calculate the spacing between elements assuming that they are uniformly spaced

(d) Calculate the directive gain of an element

(Hint: Assume uniform illumination when making this calculation and use the pattern multiplication theorem.)

Solution:

Part a:

The array broadside power gain $G_p$ is equal to

$$G_p = \frac{4\pi A_e}{\lambda^2} \qquad (6)$$

where $\lambda$ = wavelength = $\frac{c}{f_o} = \frac{3 \times 10^8}{442 \times 10^6} = 0.678$ m

$A_e$ = antenna effective area = $p_i p_R A$

where:

$p_i$ = illumination efficiency of the array = 0.65;

$p_R$ = phase shifter losses = $10^{-.18} = 0.66$;

$A$ = area of the antenna = $26.9 \times 26.9 = 723.6$ m$^2$

So,

$$A_e = (0.65)(0.66)(723.6) = 310.4 \text{ m}^2$$

Using Eq. (6) with the above values we get

$$A_e = \frac{(4\pi)(310.4)}{(0.678)^2} = 8476.75 \text{ (numeric)} = 39.28 \text{ db}$$

Part b:

The beadmwidth is given by

$$\theta = \left[\frac{41250}{G_p/p_R}\right]^{1/2} = \left[\frac{41250}{\frac{8476.75}{0.66}}\right]^{1/2} \doteq 1.8°$$

Part c:

The spacing between elements, assuming that they are uniformly spaced is

$$d = \frac{d_1}{N^{1/2}} = \frac{26.9}{72} = 0.374 \text{ m} = 0.55 \lambda$$

Part d:

The directive gain of the array is equal to:

$$G_{darray} = G_{delem} * G_{dgroup} \qquad (7)$$

where:

$$G_{dgroup} = 5184;$$

$$G_{darray} = 12795$$

So

$$G_{dee} = \frac{G_{darray}}{G_{dgroup}} = \frac{12795}{5184} = 2.47 = 3.9 \text{ db}$$

C. PROBLEM #3: JAMMER'S REPEATER GAIN, JAMMER'S OUTPUT POWER

A conical scan radar missile seeker has the following parameters:

| | |
|---|---|
| output power (peak) | $P_t$ = 1 watt |
| Boresight antenna gain | $G_a$ = 38 db |
| Antenna polarization | linear |
| Frequency | $f_o$ = 93.7 GHz |
| RF losses | $L_p$ = 3 db |
| Receiver noise bandwidth | $B_n$ = 500 MHz |
| Receiver noise figure | $F_n$ = 11 db |
| Pulse width | T = 50 ns |
| PRF | $f_p$ = 100 kHz |
| integration time | $T_i$ = 50 msec |

The clear weather attenuation at this frequency $A_t$ = 0.4 db/km and the sky temperature for cloudy conditions $T_a$ = 270 degrees K. A repeater jammer is to be designed to protect a target with RCS = 14.8 dbsm.

(a) Calculate the maximum unambiguous range for this seeker

(b) The jammer uses circular polarized antennas with 10 degree pencil beam. Calculate the repeater gain required to realize a J/s of 10 db

(c) Calculate the jammer output power required at a range R = 1 km

(d) Assume that the seeker antenna has RF losses RFL = 1 db, an illumination efficiency $r_i$ = 60%, a crossover loss $L_{co}$ = 1 db and a pencilbeam pattern which is approximately Gaussian in shape. Calculate the diamter of the seeker dish antenna

(e) Calculate the squint angle

Solution:

Part a:

The maximum unambiguous range is equal to

$$R_u = \frac{c}{2f_p} = \frac{1.5 \times 10^5 \text{ kw/sec}}{10^5 \text{ Hz}} = 1.5 \text{ km}$$

Part b:

For the calculation of the gain of the repeater we have

$$S' = \frac{P_t G_a e^{-aR} \sigma}{4\pi R^2} \tag{8}$$

and

$$J' = \frac{P_t G_a e^{-aR}}{4\pi R^2} \frac{A_e G_e G_a}{L^2 p} \text{ watts} \tag{9}$$

Substituting Eq. (8) into Eq. (9), we get

$$\frac{S'}{J'} = \frac{A_e G_e G}{L^2 p \sigma}$$

or

$$G_e = \left(\frac{J'}{S'}\right) \frac{L^2 p \sigma}{A_e G_a} \tag{10}$$

for 10° beam $\rightarrow$ $G = \frac{41250}{10^2} = 412.5 = 26.2$ db

$$A_e = \frac{\lambda^2}{4\pi} G = \frac{(3.2 \times 10^{-3} \text{ m})^2}{4\pi} 412.5 = 3.36 \times 10^{-4} \text{ m}^2$$

$$G_e = \frac{(10)(2)^2 (30.2 \text{ m}^2)}{(3.36 \times 10^{-4} \text{ m}^2)(412.5)} = 8716 \text{ or } 39.4 \text{ db}$$

Part c:

The jammer output power at a range R = 1 km is given as:

$$P_{out} = \frac{P_t G_a e^{-aR}}{4\pi R^2} \frac{A_e}{L_p} G_e \qquad (11)$$

where:

$P_t$ = output power (peak) = 1w;

$G_t$ = boresight antenna gain = 38 db ≐ 6310;

$e^{-aR} = e^{-.4/10}$ = propagation attenuation;

$A_e$ = effective antenna apertue;

$G_e$ = Repeat gain anetnna;

$L_p$ = RF losses = 3 db = 2 (numeric)

So, from Eq. (10) we get:

$$P_{out} = \frac{(1\ w)(6310)(10^{-.4/10})(3.36 \times 10^{-4}\ m^2)(8716)}{(4\pi)(10^3\ m)^2(2)}$$

$$= 0.67\ mw$$

Part d:

The effective aperture of the antennat

$$A_e = p_R p_i A = \frac{\lambda^2}{4\pi} G = p_R p_i \frac{\pi D^2}{4} \rightarrow D = \frac{\lambda}{\pi}\sqrt{G/p_R p_i}$$

where:

$p_R = 10^{-1/10} = 0.794$;

$p_i = .6$

$G = G_t + 1\ (db) = 38 + 1 = 39\ db = 7943$ (numeric)

So,

$$D = \frac{(3.2 \text{ mm})}{\pi} \sqrt{7943/(.794)(.6)} = 131 \text{ mm} = 13.1 \text{ cm}$$

Part e:

$$G = G_o \, e^{-2.776 \, (\theta_q/\theta_B)^2}$$

$$\text{-1 db crossover loss} \rightarrow \frac{G}{G_o} = .7943$$

$$.2.776(\theta_q/\theta_B)^2 = \ell n(\frac{G}{G_o})$$

$$\theta_q/\theta_B = .288$$

$$\theta_B = \sqrt{41253/G_d} = \sqrt{41253/10^4} = 2.03$$

So, the squint angle $\theta_q = (.288)(2.03) = .58$ degrees

D. PROBLEM #4: PULSE-COMPRESSION RADAR, NOISE JAMMING POWER

A shipboard pulse compression radar with a phased array antenna has the following parameters:

| | |
|---|---|
| Array size | A = 3.65 m 3.65 m |
| Frequency | $f_o$ = 3.3 GHz |
| Feed and phase shifter losses | $L_{f_p}$ = 2.5 db/element |
| Sidelobe level | S.L. = 30 db below mainbeam |
| Illumination efficiency | $p_i$ = 0.5 |
| Polarization | linear |
| Output power | $P_t$ = 4mw |
| 2TW | TW = 1000 |

| | |
|---|---|
| Weighting filter loss | $L_w$ = 3 db |
| Integration (of compressed pulses) | coherent |
| Minimum output S/N for automatic detection | $(S/N)_{min}$ = 13 db |

A raid of cruise missiles each having RCS = 3 dBsm have been launched at the ship. Two special purpose noise jamming ECN aircraft have been positioned at a range R = 100 km to provide screening. Each aircraft carrier $C_r$ = 18 carcinotrons and is configured with circular polarized high gain, steerable jamming antennas, such that the ERP = 10 kw/tube. The bandwidth of the noise has been matched to the radar receiver bandwidth. Assume that the propagation factor g = 1.

(a) Calculate the effective area and power gain of the phased array

(b) Calculate the noise jamming power at the output of the phased array(receiver input). Assume that the jammers are in the radar antenna sidelobes

(c) Calculate the single pulse echo signal power at the output of the phased array assuming a cruise missile is illuminated at a range $R_1$ = 80 kw

(d) Calculate the single pulse J/S at the receiver input and at the receiver output

(e) Calculate the number of pulses that must be integrated to achieve burnthrough against a cruise missile at a range $R_2$ = 80 km. Assume the integration efficiency is 1

Solution:

The effective area of the phased array

$$A_e = p_i p_R A = (0.5)(10^{-.25})(3.65\ m)^2 = 3.75\ m^2$$

where:

$p_i$ = the illumination efficiency;

$p_R$ = the phase shifter loss;

$A$ = area of the array.

The power gain

$$G_p = \frac{4\pi A_e}{\lambda^2} = \frac{(4\pi)(3.75\ m^2)}{\left[\frac{3 \times 10^8}{3.3 \times 10^9}\right]^2} = 5696$$

Part b:

Noise jammer power is equal to:

$$P_j = \frac{P_t\ C_j\ A_e}{4\pi R^2\ L_m} \qquad (12)$$

where:

$P_j$ = the jammer power = $10^4$ watts;

$G_j$ = jammer gain = $2 \times 18 = 36$;

$A_e$ = effective area of the array = $3.75\ m^2$

$R$ = the range = 100 km = $10^5$ m

$L_m$ = the losses = 3 db = 2 (numeric)

So

$$P_j = \frac{(2 \times 18 \times 10^4)(3.75 \times 10^{-3}\ m^2)}{(4\pi)(10^5\ m)^2(2)}$$

$$= 5.37 \times 10^{-9} \text{ watt or } -82.7 \text{ dbw or } -52.69 \text{ dbm}$$

Part c:

The single pulse echo signal power is

$$S = \frac{P_t G_p \sigma A_e}{(4\pi R_1^2)^2} \qquad (13)$$

where:

$P_t$ = output power = $4 \times 10^6$ watt;

$G_p$ = power gain of the array 5696;

$\sigma$ = RCS = 3 dbsm = 0.5 $m^2$;

$R_1$ = range of the cruise missile = 80 kw

So,

$$S = \frac{(4 \times 10^6 \text{ w})(5696)(0.5 \text{ m}^2)(3.75 \text{ m}^2)}{(4\pi)^2 (80 \times 10^3 \text{ m})^4}$$

$$= 6.61 \times 10^{-12} \text{ watt or } -111.8 \text{ dbw or } -81.8 \text{ dbm}$$

Part d:

The single pulse $(J/S)_{in}$ at the input of the receiver is

$$(J/S) = (-52.69 \text{ dbm}) - (-81.8 \text{ dbm}) = 29.2 \text{ db}$$

where:

J = jammer noise power = -52.69 dbm from part (b);

S = echo signal power = -81.8 dbm from part (c).

The single pulse S/J at the receiver output is

$$(S/J)_{out} = (S/J)_{in} + (2TW) - L_w = -29.2 \text{ db} + 30 \text{ db} - 3 \text{ db} = -2.2 \text{ db}$$

So,

$$(J/S)_{out} = +2.2 \text{ db}$$

Part e:

For perfect coherent integration we get

$$I_i(n) = n = (S/N)_{min} - (-S/J)_{out} = 13 + 2.2$$

$$= 15.2 \text{ db} \rightarrow \quad n = 33 \text{ pulses}$$

E. PROBLEM #5: STAND OFF SPOT NOISE JAMMER

A mortar location radar has the following operating characteristics:

| | |
|---|---|
| frequency | $f_o$ = 16.1 GHz |
| peak power | $P_t$ = 80 kw |
| antenna mainbeam gain | $G_a$ = 46 db |
| antenna sidelobe gain | $G_p$ = 16 db |
| PRF | $f_p$ = 8600 MHz |
| pulse width | T = 0.25 μsec |
| receiver noise figure | $F_n$ = 12 db |
| receiver noise bandwidth | $B_n$ = 5 MHz |
| antenna noise temperature | $T_a$ = 290 degrees K |
| antenna sector coverage | $S_s$ = 25 degrees |
| antenna scan rate | $S_r$ = 167 scan/sec |
| antenna polarization | linear |
| plumbing losses | $L_p$ = 3 db |

This radar is to be jammed by a standoff spot noise jammer. The jammer has the following characteristics:

| | |
|---|---|
| Type | FM/noise |
| Power output | $P_s$ = 100 w (cw) |
| PF noise bandwidth | $B_{rf}$ = 20 MHz |
| Antenna gain | $G_j$ = 23 db |
| Antenna polarization | circular |

(a) Calculate the noise jamming power which can be ejected into this radar receiver through the radar antenna sidelobes from a range R = 20 km, in clear weather. Assume a line-of-sight path and neglect atmospheric absorption

(b) With the jammer positioned at R = 20 km as described above, the J/S = 24 db, when a certain mortar round passes through the radar beam at a range $R_1$ = 4 km. If the required camouflage factor is c = 0 db, at what range will these rounds burn through?

Solution:

The noise jamming power is given by the equation

$$J = \frac{P_j G_j B_n A_e}{4 \pi R^2 L_p} \qquad (14)$$

where:

$P_j$ = jammer output power = $\frac{100 \text{ w}}{20 \text{ MHz}}$ = 5 w/MHz

$G_j$ = jammer antenna gain = 23 db = 200 (numeric)

$B_n$ = receiver noise bandwidth = 5 MHz

$A_e$ = effective antenna area = $G_p \lambda^2 / 4\pi$

where $G_p$ = antenna sidelobe gains = 16 db or 40

$\lambda$ = wavelength = $c/f_o = 3 \times 10^8 / 16.1 \times 10^9$

= 0.0186 w

So,

$$A_e = \frac{(0.0186\ w)^2}{4\pi}(40) = 1.1 \times 10^{-3}\ m^2$$

$L_p$ = plumbing losses = 3 db or 2 (numeric)

R = range = 20 km = $20 \times 10^3$ m

Thus from (14)

$$J = \frac{(5\ w/MHz)(200)(5\ MHz)(1.1 \times 10^{-3}\ m^2)}{(4\pi)(20 \times 10^3\ m)^2(2)}$$

$$J = 0.549 \times 10^{-9} \text{ watts}$$

$$J = -92.6 \text{ dbm}$$

$$J = -62.6 \text{ dbm}$$

Part b:

J is constant for a standoff jammer while S varies as $1/R^4$. Therefore

$$(J/S) = \text{const } R^4$$

$$\frac{(J/S)_2}{(J/S)_1} = \left(\frac{R_2}{R_1}\right)^4 \rightarrow R_2 = R_1\left[\frac{(J/S)_2}{(J/S)_1}\right]^{1/4},$$

$$R_2 = 4\ kw\left[\frac{1}{2S_1}\right]^{1/4} = 1 \text{ km}$$

$(J/S)_1$ = noise jammer (1) = 1

$(J/S)_2$ = noise jammer (2) = 24 db or 251 (numeric)

F. PROBLEM #6: CHAFF, AVERAGE CROSS SECTION OF DIPOLES

Suppose that a chaff package is to be designed to produce a cloud cross-section with an average value of $S_1$ = 10 dbsm. Individual dipoles are Al Fl0l with cross sectional dimensions of 0.5 × 5 miles. For frequencies of 1, 2, 5 and 10 Ghz, make a table which shows the following information:

(a) The average cross-section of one dipole

(b) The number of dipoles required to achieve an average cloud cross-section of 10 dbsm

(c) The weight of material per square meter of RCS

Assume the dipoles are uncoupled.

Solution:

$$\lambda = \frac{3 \times 10^{10}}{f} \text{ cm/sec}$$

$$\bar{\sigma} = .5\ \lambda^2$$

$$N = \frac{\sigma_{avg}}{\bar{\sigma}}$$

$$V = \left(\frac{1}{2} \times 10^{-3} \text{ in}\right)\left(5 \times 10^{-3} \text{ in}\right)\left(2.54 \text{ cm/in}\right)^2$$

$$V = \left(1.61 \times 10^{-6} \text{ cm}^2\right)\lambda$$

$$m = \rho_{AL} V,$$

$$\rho_{AL} = 2.7 \text{ gm/cm}^3$$

$$1 \text{ lb} = 454 \text{ gm}$$

| f [GHz] | λ [cw] | $\bar{\sigma}$[cm$^2$] | N | V [cm$^3$] | w[grms] | $\frac{w}{\sigma_{avg}}$[gr/m$^2$] | $\frac{\#}{\sigma_{avg}}$[lb/m$^2$] |
|---|---|---|---|---|---|---|---|
| 1 | 30 | 135 | 741 | 0.35 | 0.97 | 0.096 | 0.0002 |
| 2 | 15 | 33.75 | 2962.9 | 0.71 | 1.9 | 0.19 | 0.0004 |
| 5 | 6 | 5.4 | 18.5 K | 1.8 | 4.8 | 0.48 | 0.0001 |
| 10 | 3 | 1.35 | 74.07 K | 3.6 | 9.7 | 0.96 | 0.002 |

## G. PROBLEM #7: SIGNAL-TO-CLUTTER RATIO, POWER SPECTRA DENSITY OF JAMMER

An MTI radar with a single delay line canceler has the following operating characteristics:

| | |
|---|---|
| Peak power | $P_t$ = 1 MW |
| Pulse width | T = 14 μs |
| PRF | $f_p$ = 800 Hz |
| Antenna gain | $G_a$ = 26 db |
| Frequency | $f_o$ = 1 GHz |
| Receiver noise bandwidth | $B_n$ = 1.5 MHz |
| Antenna scan rate | $W_m$ = 10 RPM |
| Aziumth beamwidth | $\theta_B$ = 3.9 degrees |
| Receiver noise figure | $F_n$ = 9.0 db |
| Antenna noise temperature | $T_a$ = 100 degrees K |
| Plumbing losses | $L_p$ = 2 db |
| Display | PPI (video int.) |
| False alarm probability | $P_{fa}$ = 1E-12 |

(a) For the non-MTI mode, calculate the maximum range at which this radar can detect a non-fluctuating 0 dbsm target with a detection probability $P_d$ = 0.9

(b) Suppose that this radar is operated in the MTI mode against a target aircraft with RCS = 10 dbsm immersed

in a chaff cloud with a cross section of 500 sq. meters. The target is 30 km from the radar and closing with radial velocity r = 300 knots. Assume that the power spectral density of the chaff return is as given in Skolnik, Figure 4.29. Calculate the target signal-to-clutter ratio at the output of the delay line canceler.

Solution:

Part a:

The maximum radar range may be written as

$$R_{max} = \left[\frac{P_t G_a A_e \sigma I_i(n)}{(4\pi)^2 k T_a + T_e) B_n (S/N)_1 L_s}\right]^{1/4}$$

where:

$P_t$ = peak power = $10^6$ W;

$G_a$ = antenna gain = 26 db = 398 (numeric);

$A_e$ = effective area

$$= \frac{\lambda^2 G_a}{4\pi} = \left(\frac{c}{f_u}\right)^2 \frac{G_a}{4\pi} = \left(\frac{3 \times 10^9}{10^9}\right)^2 \frac{(398)}{4\pi} = 2.85 \text{ m}^2$$

$\sigma$ = radar cross section = 1 $m^2$

$$kT_e = (F_n - 1)T_o = (7.94-1)290 = 2013.55$$

$$k(T_a+T_e)B_n = 1.38 \times 10^{-23}(100+2013.55)1.5 \times 10^6$$

$$= 43.7 \times 10^{-15} \text{ w}$$

$(S/N)_1$ = signal-to-noise ratio (from Figure 2.7 (Skolnik, Pg. 28))

= 15.8 db = 38(for $P_{fa}$ = 1E-12 and $P_d$ = 0.9)

$$\bar{n} = \text{pulses integrated} = f_p \frac{\theta_B}{w_m}$$

$$= (800 \text{ sec}^{-1})(3.9°)/(360°/6 \text{ sec}) = 52 \text{ pulses}$$

$$I_1(52) \doteq 23.5 = 13.7 \text{ db (Figure 2.8 a/b (Skolnik, Pg. 31))}$$

Thus,

$$R_{max} = \left[\frac{(10^6 \text{ w})(398)(2.85 \text{ m}^2)(1 \text{ m}^2)(23.5)}{(4\pi)^2(43.7 \times 10^{-15} \text{ w})(38)(1.58)}\right]^{1/4}$$

$$R_{max} = 89.46 \text{ km}$$

Part b:

Since the target and chaff cloud are only 30 km from the radar the returns will be well above the thermal noise level and the receiver will be clutter dominated.

$$\frac{S_{avg}}{C_{out}} = \frac{|H(f_d)|^2 S_{in}}{C_{in}/CA} = |H(f_d)|^2 CA(S/C)_{in}.$$

$$f_d(\text{Hz}) = \frac{1.03\, U_r}{\lambda} = \frac{1.03(300 \text{ knots})}{0.3 \text{ m}} \text{ (Skolnik, Eq. 3.26)}$$

$$f_d = 1030 \text{ Hz}$$

$$|H(f_d)|^2 = |2 \sin(\pi f_d T_p)|^2 = 4 \sin^2[\pi(1030/800)]$$

$$= 2.47$$

$$CA = \frac{.5}{1 - e^{-2\pi^2 T_p^2 \sigma_c^2}} \doteq \frac{a f_p^2}{2\pi^2 f_o^2} \quad (G_c << f_p)$$

(Eq. 4.23 and 4.24 from Skolnik, Pg. 132-133)

From Figure 4.29 (Skolnik) for chaff $a = 10^{16}$ and

$$\sigma_c^2 = \frac{f_o^2}{2a} = 50 \quad \text{so} \quad CA = \frac{(10^{16})(800)^2}{2\pi^2(10^9)^2} = 324 = 25.1 \text{ db}$$

$$(S/C)_{in} = \sigma_{tH}/\sigma_{chaff} = 10/500 = 1/50 = -17 \text{ db}$$

So,

$$(S/C)_{out} = (1/50)(2.47)(324) = 16 = 12 \text{ db}$$

H. PROBLEM #8: WEIGHTING FILTERS

An airborne periscope detecting radar has the following characteristics:

| | |
|---|---|
| Frequency | $f_o$ = 9.510 GHz (linear chirp) |
| Peak power | $P_t$ = 500 kw |
| PRF | $f_p$ = 1500 Hz |
| Pulse width | T = 500 nanoseconds |
| Weighting filter | Hamming |
| Antenna gain | $G_a$ = 35 db |
| Polarization | Vertical |
| Azimuth beamwidth | $\theta_B$ = 2.4 degrees |
| Antenna scan rate | $w_m$ = 300 RPM |
| Plumbing losses | $L_p$ = 5 db |
| $R_x$ noise figure | $R_x$ = 7.5 db |

An ASW aircraft with this radar encounters a submarine with periscope exposed under the following conditions:

| | |
|---|---|
| Aircraft altitude | $H_a$ = 2000 ft |
| Range to submarine | $R_s$ = 16 kyards |
| Periscope RCS | RCS = 1 $m^2$ |

(a) Assume that the sea clutter spikes resolved by this high resolution radar have an average duration $t_{fa}$ = 2 sec and that the sea state 2-3 statistics shown in [Ref. 1, Figure 13.5] apply. How many db above the median clutter level must a threshold be set to achieve a 100 seconds false alarm time when the receiver is clutter dominated?

(b) Calculate the single pulse signal-clutter power ratio at the radar receiver input

(c) At the output of the weighting filter calculate the 3 db width of the compressed pulse and the peak signal-mean clutter power ratio

(d) Assume that a 5 second scan-scan post detection integration period is employed to separate targets (which remain) from clutter spikes (which go away). Calculate the integration improvement

Solution:

Part a:

For the clutter waveform

$$P_{fa} = \frac{t_{fa}}{T_{fa}} = \frac{2 \text{ sec}}{100 \text{ sec}} = 0.02$$

Using Figure 13.5 (Skolnik) for $P_{fa} = 0.02$, $\sigma_c/\sigma_{cmed} = 12.5$ db threshold must be set 12.5 db above the median clutter power level.

Part b:

From Eq. 13.6 (Skolnik, Pg. 472), the signal power S returned from a target with cross section $\sigma$ is

$$S = \frac{P_t G_a \sigma A_e}{(4\pi)^2 R^4 L_p}$$

where:

$P_t = 500 \times 10^3$ w = 87 dbm

$G_a$ = 35 db = 3162 (numeric)

$\sigma = 1\ w^2 = 0$ db

$A_e = (\lambda^2/4\pi)G_a = \frac{(0.03)^2}{4\pi}\ 3162 = .227\ m^2 = -6.4$ dbm

$4\pi$ = 11 db

$R = 16 \times 10^3 = 9.09$ mi = 14.64 km = 41.65 dbm

$L_p$ = 5 db

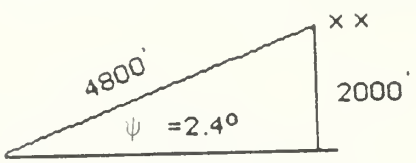
$S$ = [87 dbm + 35 - 6.470] - [11 × 2 + 41.65*4 + 5]

= -78 dbm

The echo from surface clutter is

$$C = \frac{P_t\ G_a\ A_e\ \sigma_o\ \theta_B\ (CT/2)\sec(\psi)}{(4\pi)^2\ R^3\ (L_p/2)}$$ (Eq. 13.5 from Skolnik, Pg. 472)

Part b:




$\psi$ = grazing angle

$\theta_B$ = 2.4° = .042 rad = -13.8 dbrad

$CT/2 = (1.5 \times 10^8\ m/s)(0.5 \times 10^{-6}\ sec)$

$\sec \psi = 1/\cos \psi \doteq 1 \quad (\psi = 2.4°)$

From Figure 13.3 (Skolnik, Pg. 475), $\sigma_o$ = -32 db

Thus

$$C = [87 \text{ dbm} + 35 - 6.4 - 32 - 13.8 + 18.6 + 0] - [11 \times 2 + 41.65 \times 3 + 2.5] = -61.1 \text{ dbm}$$

So,

$$(S/C)_{in} = (-78 \text{ dbm}) - (-61.1 \text{ dbm}) = -16.9 \text{ db}$$

Part c:

For the Hamming filter [Ref. 1], the peak sidelobe $S_{LL} = -42.8$ db, the loss = 1.34 and the relative mainlobd width = 1.5. So the width of the compressed pulse at the output of the weighting filter is

$$T_c = \frac{T}{TW} \times 1.5 = \frac{(500 \times 10^{-9} \text{ sec})(1.5)}{(500 \times 10^{-9} \text{ sec})(0.5 \times 10^{9} \text{ Hz})}$$

$$= 3 \times 10^{-9} \text{ sec}$$

The improvement in S/C is

$$10 \log_{10}(2 \text{ TW}) - 1.34 \text{ db} = 25.7 \text{ db}$$

so

$$(S/C)_{out} = (-16.9 \text{ db}) + (25.7 \text{ db}) \doteq 8 \text{ db}$$

Part d:

$$\# \text{ hits/scan} = \frac{\theta_B f_p}{6 w_n} = \frac{2.4° \text{ v } 1500}{6 \text{ v } 300} = 2$$

$$\# \text{ hits} = (2 \frac{\text{hits}}{\text{scan}}) \text{ v } (\frac{300}{60}) \text{ v } (5 \text{ sec}) = 50 \text{ hits}$$

From Figure 2.80 (Skolnik, Pg. 31) $I_i(5) = 25.118 = 14$ db with integration (S/C) = 14 db + 8 db = 22 db.

I. PROBLEM #9: MTI FILTERS, CHAFF DIPOLES

An MTI radar has the following characteristics:

| | |
|---|---|
| Frequency | $f_o$ = 1.3 GHz |
| Peak power | $P_t$ = 2 mw |
| Antenna gain | $G_a$ = 35 db |
| Azimuth beamwidth | $\theta_B$ = 1.3 degrees |
| Elevation coverage | 0.2-45 degrees |
| Antenna scan rate | $w_n$ = 5 RPM |
| PRF | $f_p$ = 360 Hz |
| Pulse width | T = 6 μsec |
| Receiver noise figure | $F_n$ = 8 db |

Assume that this radar has a 2 pulse canceler. An aircraft with RCS = 10 dbsm at a range of 100 km is to be protected with a chaff corridor. Assume that the chaff return has Gaussian power spectral density with RMS velocity spread 1.0 m/s. Calculate the number of half wave chaff dipoles per resolution cell required to produce a minimum clutter-target signal ratio of 10 db at the output of the MTI filter.

Solution:

The best improvement the delay line canceler will provide is

$$\frac{(S/C)_{out}}{(S/C)_{in}} = \frac{C_{in}}{C_{out}} \times \frac{S_{out}}{S_{in}} = CA|H(f)|^2 = \frac{f_p^2 \lambda^2}{16\pi^2 \sigma_u^2} 4$$

$$= \frac{(360 \text{ Hz})^2 (.231 \text{ w})^2}{4\pi^2 (1 \text{ w/sec})^2}$$

$$I_{max} = 175 = 22.4 \text{ db}$$

With the target at 100 km, the receiver will be clutter dominated. We require

$$(S/C)_{in} = -10 \text{ db} - 22.4 \text{ db} = \frac{1}{1750}$$

or

$$\frac{\sigma_t}{N\bar{\sigma}} = \frac{\sigma_t}{N(0.15\lambda^2)} = (S/C)_{in}$$

$$N = \frac{10}{(0.15 \times .231^2 w^2)(1/1750)} = 2.19 \times 10^6 \text{ dipoles}$$

(in resolution cell)

## J. PROBLEM #10: MINIMUM DETECTABLE SIGNAL

An HF compressive receive is to be designed to sweep the 2-32 MHz band 25 times per second and to provide a frequency resolution of 2 Khz.

(a) Calculate the bandwidth and time delay required of the compressive filter for this receiver

(b) Calculate the MDS of this receiver, assuming a receiver noise figure of 3 db and an antenna noise temperature of 290°K

Solution:

Part a:

$$\frac{W}{T} = \frac{32 - 2}{1/25 \text{ sec}} = \frac{30 \text{ MHz}}{1/25 \text{ sec}} = 750 \text{ MHz/sec}$$

$$T1 = \frac{1}{\Delta f} = \frac{1}{2 \times 10^3 \text{ Hz}} = .5 \times 10^{-3} \text{ sec} \quad \text{(time delay)}$$

$$W = \left(\frac{W1}{T}\right) \times T = 750 \times (0.5 \times 10^{-3}) = 375 \text{ kHz} \quad \text{(bandwidth)}$$

Part b:

$$T_e = (F-1)290) = (1.99-1)290 = 288.626 \text{ K}$$

$$NDS = k(T_a + T_e)B_n \frac{1}{2Tw} \quad \text{but } B_n = w \text{ so}$$

$$NDS = k(T_a + T_e)\frac{1}{2T} = -170.9 + 3 + 30 \text{ dbm} = -138 \text{ dbm}$$

# V. CONCLUSION

The programs were written for solving problems of radar and Electronic Warfare. They are in easy-to-understand Basic language. They were written in the interactive method. As a result these programs are "user friendly." They were very time consuming to write in this mode. The interactive method is very amenable to work with and should be helpful to the Naval officer, in the field of radar and electronic warfare. Using the same problems but with parameters of other systems, one can understand the performance of different types of radar and jammers.

Many subroutines and interation loops are used so that even one who has little experience in programming can read and easily comprehend the programs and can expand or modify them according to his needs.

The author hopes that these programs will be an assistance to students, and Naval officers involved in radar and electronic warfare.

The programming language is Microsoft Basic so that anyone can work on these programs on any IBM or IBM-compatible computer as well as Apple microcomputers without requiring any modifications in these programs.

These programs may be used on boardship to aid in the technical aspects of a tactical operation. They may be used by the Naval officer in program management in radar and

electronic warfare systems or in evaluation and design at a Naval laboratory. On board ship as a combat information center officer or Electronic Warfare officer these problems addressed arise inumerable times. As an example, your ship is in the Indian Ocean and there is a threat of an antiship cruise missile whose radar parameters you are aware of (i.e., Harpoon, Automat, or Exocet) and it is your responsibility to provide shipboard defense. If per chance you have worked with these problems and you are familiar with characteristics of your defense systems, the more viable ECM action can be made. For instance, you are aware of your ships radar cross section as a function of aspect angle relative to the missile threat. You are aware of the radar cross section of your chaff loads and you are aware of the power outputs and characteristics of your decoys. Using the enclosed programs and the variations of the parameters associated with them should allow you to obtain a better understanding of what actions you should take for ships defense. It is only through the working of many problems of these types in many different tactical scenarios that a proper technical expertise in radar and EW can be obtained.

Lastly, the author believes that this group of problems were selected to include a variety of timely and useful situations that one may encounter in the radar and electronic warfare field.

# APPENDIX A

A listing of the radar computer programs is provided and an output of the results for each one of these programs is also included.

```
10  PRINT : PRINT TAB(30); " PROBLEM # 1"
20  PRINT TAB(30); " ----------"
30  LPRINT : LPRINT TAB(30); " PROBLEM # 1"
40  LPRINT TAB(30); " ----------"
50  PRINT : PRINT "ENTER THE BANDWIDTH OF THE AMPLIFIER WITHOUT UNITS :  B=?"
60   INPUT B
70  PRINT : PRINT  "WHAT ARE THE UNITS OF THE BANDWIDTH?"
80   PRINT  "1.  HZ "
90   PRINT  "2. KHZ"
100 PRINT  "3. MHZ"
110 PRINT  "4. GHZ"
120 INPUT A$      'input selection
130 IF A$ = "1" THEN B=B
140 IF A$ = "2" THEN B=B* 1000
150 IF A$ = "3" THEN B=B* 1000000!
160 IF A$ = "4" THEN B=B* 1000000000#
170 PRINT : PRINT " ENTER THE FALSE ALARM TIME WITHOUT UNITS: T=?"
180  INPUT T
190 PRINT : PRINT " WHAT ARE THE UNITS OF THE FALSE ALARM TIME?"
200 PRINT "1. seconds"
210 PRINT "2. minutes"
220 PRINT "3. hours"
230 INPUT B$  'input selection
240 IF B$="1" THEN T=T
250 IF B$="2" THEN T=T*60
260 IF B$="3" THEN T=T*3600
270 REM : calculation of the threshold -to-rms ratio
280 LET X=SQR(2*LOG(B*T)) ' numeric value
290 LET M=.4342945#
300 LET X1=10*M*LOG(X) ' db value
310 IF A$="1" THEN LPRINT : LPRINT " THE BANDWIDTH B=";B;"HZ"
320 IF A$="2" THEN B=B/1000 : LPRINT : LPRINT " THE BANDWIDTH B=";B;"KHZ"
330 IF A$="3" THEN B=B/1000000! : LPRINT : LPRINT  " THE BANDWIDTH B=";B;"MHZ"
340 IF A$="4" THEN B=B/1000000000# : LPRINT : LPRINT " THE BANDWIDTH B=";B;"GHZ"
350  IF B$="1" THEN LPRINT : LPRINT  " THE FALSE ALARM TIME T=";T;"sec"
```

```
360 IF B$="2" THEN T=T/60 :LPRINT :LPRINT  " THE FALSE ALARM TIME T=";T;"min"
370 IF B$="3" THEN T=T/3600 : LPRINT : LPRINT  " THE FALSE ALARM TIME T=";T;"Hrs"
380 PRINT : PRINT " THE THRESHOLD-TO-RMS NOISE VOLTAGE
 V/SQR(YO)=";X;"(numeric)";"or";X1;"(db)"
390 LPRINT :LPRINT  " THE THRESHOLD-TO-RMS NOISE VOLTAGE
 V/SQR(YO)=";X;"(numeric)";"or";X1;"(db)"
400 PRINT : PRINT  " DO YOY WANT TO USE THIS PROGRAM FOR DIFFERENT OR THE SAME DATA
 Y/N?"
410 INPUT C$
420 IF LEFT$(C$,1)="Y" OR LEFT$(C$,1)="y"  THEN 40
430 END
```

PROBLEM#1

THE BANDWIDTH B= 4MHZ
THE FALSE ALARM TIME T= 5 min
THE THRESHOLD-TO-RMS NOISE VOLTAGE V/SQR(YO)= 6.466156 (numeric) or 8.106462 (db)

THE BANDWIDTH B= 4MHZ
THE FALSE ALARM TIME T= 50 min
THE THRESHOLD-TO-RMS NOISE VOLTAGE V/SQR(YO)= 6.812954 (numeric) or 8.333355 (db)

THE BANDWIDTH B= 4MHZ
THE FALSE ALARM TIME T= 500 min
THE THRESHOLD-TO-RMS NOISE VOLTAGE V/SQR(YO)= 7.142935 (numeric) or 8.538767 (db)

```
10  PRINT : PRINT TAB(30); " PROBLEM #2 "
20  PRINT TAB(30); " ----------"
30  LPRINT : LPRINT TAB(30); " PROBLEM #2 "
40  LPRINT TAB(30); " ----------"
50  PRINT : PRINT " ENTER THE NUMBER OF THE m NOISE PULSES "
60  INPUT A     ' # OF m NOISE PULSES
70  PRINT : PRINT " 1. m="A
80  LPRINT : LPRINT " 1. m="A
90  PRINT : PRINT " ENTER THE NUMBER OF THE n SIGNAL-PLUS-NOISE PULSES"
100  INPUT B    ' # OF n SIGNAL-PLUS-NOISE PULSES
110  PRINT : PRINT " 2. n="B
120  LPRINT : LPRINT " 2. n="B
130  PRINT : PRINT " FROM Fig. 2.8 (b) (SKOLNIK Pg 31) YOU CAN FIND THE INTEGRATION LOSS
 FOR L1(m+n) AND L1(n), SINCE YOU KNOW Pd,m,n, WHICH ARE GIVEN IN THE PROBLEM"
140  LET C=A+B
150  PRINT : PRINT " ENTER THE VALUE OF THE L1("C")"
160  INPUT D   'THIS IS THE VALUE OF L1(m+n) IN db"
170  PRINT : PRINT " 3. THE INTEGRATION LOSS FOR L1("C")""="D;"db"
180  LPRINT : LPRINT " 3. THE INTEGRATION LOSS FOR L1("C")""="D;"db"
190  PRINT : PRINT " ENTER THE VALUE OF THE L1("B")"
200  INPUT E   ' THIS IS THE VALUE OF L1(n) IN db"
210  PRINT : PRINT " 4. THE INTEGRATION LOSS FOR L1("B")""="E"db"
220  LPRINT : LPRINT " 4. THE INTEGRATION LOSS FOR L1("B")""="E"db"
230'*****************************************
240  REM : CALCULATION OF THE COLLAPSING LOSS
251'*****************************************
260  LET F=D-E : F1=F/10 : F1=10^F1  ' CONVERTION FROM "db" TO "NUMERIC"
270  PRINT : PRINT " 5. THE COLLAPSING LOSS L1("A","B")""="F1;"NUMERIC";" OR";F;"db"
280  LPRINT : LPRINT " 5. THE COLLAPSING LOSS L1("A","B")""="F1;"NUMERIC";" OR";F;"db"
290  PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
300  INPUT G$   'INPUT SELECTION
310  IF LEFT$(G$,1)="Y" OR LEFT$(G$,1)="y" THEN LPRINT : LPRINT : LPRINT TAB(15);"
 *****************************************":GOTO50
320  END
```

PROBLEM*2

1. m= 10
2. n= 10
3. THE INTEGRATION LOSS FOR L1( 20 )= 1.9 db
4. THE INTEGRATION LOSS FOR L1( 10 )= 1.3 db
5. THE COLLAPSING LOSS L1(10,10 )= 1.148154 NUMERIC OR .6 db

**********

1. m= 90
2. n= 10
3. THE INTEGRATION LOSS FOR L1( 100 )= 4.1 db
4. THE INTEGRATION LOSS FOR L1( 10 )= 1.3 db
5. THE COLLAPSING LOSS L1( 90,10 )= 1.905461 NUMERIC OR 2.8 db

```
10    REM :          **** MAIN PROGRAM ****
20    PRINT : PRINT TAB(30); " *** PROBLEM #3 ***"
30    LPRINT : LPRINT TAB(30); " *** PROBLEM #3 ***"
40    GOSUB 90    : GOSUB 430
50    GOSUB 780   : GOSUB 840
60    GOSUB 930   : GOSUB 1180
70    GOTO 1360
80    REM  ************************************************
90    REM          SUBPROGRAM THAT INPUTS THE DATA
100   REM  ************************************************
110   PRINT : PRINT " ENTER THE MAGNETRONS PEAK POWER Pt IN MEGAWATTS"
120    INPUT Pt
130   PRINT : PRINT " ENTER THE PULSE WIDTH Tw IN MICROSEC"
140    INPUT Tw
150   PRINT : PRINT " ENTER THE PULSE REPETITION FREQUENCY fp IN HZ"
160    INPUT fp
170   PRINT : PRINT " ENTER THE OPERATION WAVELENGTH IN CENTEMETERS"
180    INPUT l
190   PRINT : PRINT " ENTER THE EFFECTIVE ANTENNA APERTURE Ae IN SQUARE METERS"
200    INPUT Ae
210   PRINT : PRINT " ENTER THE #OF HITS INTEGRATED n"
220    INPUT n
230   PRINT :PRINT " ENTER THE NOISE BANDWIDTH IN MEGAHERTZ"
240    INPUT Bn
250   PRINT : PRINT " ENTER THE RECEIVER NOISE FIGURE Ff IN db"
260    INPUT Ff
270   PRINT : PRINT " ENTER THE PLUMBING LOSSES Lp1 IN db"
280    INPUT Lp1
290   PRINT : PRINT " ENTER THE BEAM SHAPE Lbs IN db"
300    INPUT Lbs
310   PRINT : PRINT " ENTER THE FACTOR BY WHICH THE INTEGRATION EFFICIENCY IS REDUCED"
320    INPUT e
330   PRINT : PRINT " ENTER THE FALSE ALARM PROBABILITY Pf"
340    INPUT Pf
350   PRINT : PRINT " ENTER THE PROBABILITY OF DETECTION Pd"
```

```
360   INPUT Pd
370   PRINT : PRINT " ENTER THE TARGET AVERAGE CROSS SECTION Sav IN SQUARE METERS"
380   INPUT Sav
390   PRINT : PRINT " ENTER THE CASE THAT YOU ARE : CASE1,CASE2...?"
400   INPUT A$
410   RETURN
420  REM ************************************
430   REM SUBROGRAM THAT PRINTS THE INPUT DATA
440  REM ************************************
450   LPRINT: LPRINT "G I V E N" : LPRINT "---------"
460   PRINT : PRINT "1. Pt=";Pt;"MW" SPC(17); " : MAGNETRON'S PEAK POWER"
470   LPRINT : LPRINT "1. Pt=";Pt;"MW" SPC(17); " : MAGNETRON'S PEAK POWER"
480   PRINT : PRINT  "2I Tw=";Tw;"MICSEC" SPC(13); " : PULSE WIDTH "
490   LPRINT : LPRINT "2I Tw=";Tw;"MICSEC" SPC(13); " : PULSE WIDTH "
500   PRINT : PRINT "3. fp=";fp;"HZ" SPC(15); " : PULSE REPETITION FREQUENCY "
510   LPRINT : LPRINT "3. fp=";fp;"HZ" SPC(15); " : PULSE REPETITION FREQUENCY "
520   PRINT : PRINT  "4. l=";l;"centimeters" SPC(8); " : OPERATION WAVELENGTH "
530   LPRINT : LPRINT  "4. l=";l;"centimeters" SPC(8); " : OPERATION WAVELENGTH "
540   PRINT : PRINT "5. Ae=";Ae;"square meters" SPC(4); " : EFFECTIVE ANTENNA APERTURE "
550  LPRINT : LPRINT "5. Ae=";Ae;"square meters" SPC(4); " : EFFECTIVE ANTENNA APERTURE "
560   PRINT : PRINT "6. n=";n SPC(19); " : #OF HITS INTEGRATED "
570   LPRINT : LPRINT "6. n=";n SPC(19); " : #OF HITS INTEGRATED "
580   PRINT :PRINT "7. Bn=";Bn;"MHZ" SPC(16); " : NOISE BANDWIDTH"
590   LPRINT : LPRINT "7. Bn=";Bn;"MHZ" SPC(16); " : NOISE BANDWIDTH"
600   PRINT : PRINT "8. Ff=";Ff;"db" SPC(16); " : RECEIVER NOISE FIGURE"
610   LPRINT : LPRINT "8. Ff=";Ff;"db" SPC(16); " : RECEIVER NOISE FIGURE"
620   PRINT : PRINT "9. Lp l=";Lp l;"db" SPC(16); " : PLUMBING LOSSES"
630   LPRINT : LPRINT "9. Lp l=";Lp l;"db" SPC(16); " : PLUMBING LOSSES"
640   PRINT :PRINT " 10. Lbs=";Lbs;"db" SPC(15); " : BEAM SHAPE"
650   LPRINT :LPRINT " 10. Lbs=";Lbs;"db" SPC(15); " : BEAM SHAPE"
660   PRINT : PRINT " 11. a=";a SPC(17); " : FACTOR BY WHICH INTEGRATION EFF. IS REDUCED"
670   LPRINT : LPRINT " 11. a=";a SPC(17); " : FACTOR BY WHICH INTEGRATION EFF. IS REDUCED"
680   PRINT : PRINT " 12. Pf=";Pf SPC(14); " : FALSE ALARM PROBABILITY"
690   LPRINT : LPRINT " 12. Pf=";Pf SPC(14); " : FALSE ALARM PROBABILITY"
700   PRINT : PRINT " 13. Pd=";Pd SPC(16); " : PROBABILITY OF DETECTION"
```

```
710   LPRINT : LPRINT " 13. Pd=";Pd SPC(16) " : PROBABILITY OF DETECTION"
720   PRINT : PRINT " 14. Sav=";Sav;"sq.meters"SPC(8);" : TARGET AVERAGE CROSS SECTION"
730   LPRINT : LPRINT " 14. Sav=";Sav;"sq.meters" SPC(8) " : TARGET AVERAGE CROSS SECTION"
740   PRINT : PRINT " 15. YOU 'RE CASE IS" SPC(10);A$
750   LPRINT : LPRINT " 15. YOU 'RE CASE IS" SPC(10);A$
760   RETURN
770  REM: ********************************************
780   REM :   SUBR. THAT CALCULATES THE MAX. UNAB. RANGE
790  REM: ********************************************
800   LET C=3*10^8                'm/s
810   LET Runab=C/(2*fp)
820   RETURN
830  REM: ********************************************
840   REM :   SUBR. THAT PRINTS THE OUTPUT FOR PART a
850  REM: ********************************************
860   PRINT : PRINT "PART a:"
870   LPRINT : LPRINT "PART a:"
880   LPRINT "-------"
890   PRINT : PRINT " 1(a). Runab=";Runab/1000;"KM", " : THE MAX. UNAB. RANGE"
900   LPRINT : LPRINT " 1(a). Runab=";Runab/1000;"KM", " : THE MAX. UNAB. RANGE"
910   RETURN
920  REM: ********************************************
930   REM :   SUBR. THAT CALCULATES THE MAX. RANGE
940  REM: ********************************************
950   LET Bn=Bn*10^6              'CONVERTION FROM MHZ TO HZ
960   LET Pt=Pt*10^6              'CONVERTION FROM Mw TO w
970   LET K=1.38*(10^(-23))       'BOLTZMAN'S CONSTANT IN j/deg.
980   LET T0=290                  'STANDARD TEMPERATURE IN KELVIN
990   LET PI=3.14159
1000  LET Ff=Ff/10 : Ff1=10^Ff    'CONVERTION FROM db TO NUMERIC
1010  LET Ls=Lp1+Lbs              'SYSTEM LOSSES IN db
1020  LET Ls1=Ls/10 : Ls2=10^Ls1  'CONVERTION FROM db TO NUMERIC
1030  LET l=l/100                 'CONVERTION FROM cm TO m
1040  PRINT : PRINT " FROM Fig. 2.7 (SKOLNIK Pg. 28) YOU CAN FIND THE (S/N)1 SINCE YOU KNOW
 Pd AND Pf"
```

```
1050  PRINT : PRINT " ENTER THE VALUE OF THE (S/N)1 IN db"
1060  INPUT A1
1070  PRINT : PRINT "SINCE YOU ARE IN CASE2 FROM Fig. 2.23 (SKOLNIK Pg. 48) YOU CAN FIND
THEADDITIONAL (S/N) 1ad"
1080  PRINT : PRINT " ENTER THE VALUE OF THE (S/N) 1ad"
1090  INPUT A2
1100  LET A=A1+A2 : A3=A/10 : A4=10^A3     THIS IS THE VALUE OF THE (S/N) 1tot IN db AND
INNUMERIC
1110  PRINT : PRINT " SINCE YUO KNOW THE #OF HITS INTEGRATED (NONCOHERENT) FROM Fig.
2.24 (SKOLNIK Pg. 49) YOU CAN FIND THE INTEGRATION IMR. FACTOR I1"
1120  PRINT : PRINT " ENTER THE VALUE OF THE INTEGRATION IMR. FACTOR"
1130  INPUT I1
1140  LET I11=I1/10 : I12=10^I11
1150LETRmax=SQR(SQR((Pt*(Ae^2)*Sav*I12*.85)/(4*PI*K*T0*Ff1*Bn*(1^2)*A4*Ls2)))
1160  RETURN
1170 REM:**************************************
1180  REM :  SUBR. THAT PRINTS THE OUTPUT FOR PART b
1190 REM:**************************************
1200  PRINT : PRINT : PRINT  " PART b:"
1210  LPRINT : LPRINT : LPRINT " PART b:"
1220  LPRINT " -------"
1230  PRINT : PRINT " 2(a). Ls=";Ls;"db", " : TOTAL SYSTEM LOSSES"
1240  LPRINT : LPRINT " 2(a). Ls=";Ls;"db", " : TOTAL SYSTEM LOSSES"
1250  PRINT : PRINT " 2(b). (S/N) 1=";A1;"db", ": SIGNAL-TO-NOISE RATIO"
1260  LPRINT : LPRINT " 2(b). (S/N) 1=";A1;"db", ": SIGNAL-TO-NOISE RATIO"
1270  PRINT : PRINT " 2(c). (S/N) 1ad=";A2;"db", ": ADDITIONAL SIGNAL-TO-NOISE RATIO"
1280  LPRINT : LPRINT " 2(c). (S/N) 1ad=";A2;"db", ": ADDITIONAL SIGNAL-TO-NOISE RATIO"
1290  PRINT : PRINT " 2(d). (S/N)tot=";A;"db", " : TOTAL SIGNAL-TO-NOISE RATIO"
1300  LPRINT : PRINT " 2(d). (S/N)tot=";A;"db", " : TOTAL SIGNAL-TO-NOISE RATIO"
1310  PRINT : PRINT " 2(e). I1(n)=";I1;"db", " : INTEGRATION IMR. FACTOR"
1320  LPRINT : LPRINT " 2(e). I1(n)=";I1;"db", " : INTEGRATION IMR. FACTOR"
1330  PRINT : PRINT " 2(f). Rmax=";Rmax/1000;"KM", " : MAXIMUM RANGE"
1340  LPRINT : LPRINT " 2(f). Rmax=";Rmax/1000;"KM", " : MAXIMUM RANGE"
1350  RETURN
1360  PRINT : PRINT " DO YOU WANT TO TRY FOR DIFFERENT OR THE SAME DATA Y/N?"
```

```
1370  INPUT C$
1380  IF LEFT$(C$,1)="Y" OR LEFT$(C$,1)="y"  THEN 40
1390  END
```

*** PROBLEM #3 ***

GIVEN

1. Pt= 1 MW : MAGNETRON'S PEAK POWER
2. Tw= 1 MICSEC : PULSE WIDTH
3. fp= 250 HZ : PULSE REPETITION FREQUENCY
4. l= 10 centimeters : OPERATION WAVELENGTH
5. Ae= 200 square meters : EFFECTIVE ANTENNA APERTURE
6. n= 10 : #OF HITS INTEGRATED
7. Bn= 1 MHZ : NOISE BANDWIDTH
8. Ff= 10 db : RECEIVER NOISE FIGURE
9. Lpl= 3 db : PLUMBING LOSSES
10. Lbs= 2 db : BEAM SHAPE
11. a= .85 : FACTOR BY WHICH INTEGRATION EFF. IS REDUCED
12. Pf= 1E-08 : FALSE ALARM PROBABILITY
13. Pd= .99 : PROBABILITY OF DETECTION
14. Sav= 1 sq.meters : TARGET AVERAGE CROSS SECTION
15. YOU'RE CASE IS : CASE2

PART a:

1(a). Runab= 600 KM : THE MAX. UNAB. RANGE

PART b:

2(a). Ls= 5 db : TOTAL SYSTEM LOSSES
2(b). (S/N)1= 15.9 db : SIGNAL-TO-NOISE RATIO
2(c). (S/N)1ad= 17.2 db : ADDITIONAL SIGNAL-TO-NOISE RATIO
2(d). (S/N)tot= 33.1 db : TOTAL SIGNAL-TO-NOISE RATIO
2(e). I1(n)= 25 db : INTEGRATION IMR. FACTOR
2(f). Rmax= 758.5743 KM : MAXIMUM RANGE

```
10  PRINT : PRINT TAB(30); " PROBLEM #4"
20  LPRINT : LPRINT TAB(30); " PROBLEM #4"
30  LPRINT TAB(30); " ----------"
40 '*******************************
50  REM :  MAIN PROGRAM
60 '*******************************
70  GOSUB 160 : GOSUB 310
80  GOSUB 440 : GOSUB 570
90  PRINT : PRINT "DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N ?"
100 INPUT A$
110 IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y" THEN 70
120 END
130'*****************************
140 REM : SUBROUTINES
150'*****************************
160 '***** SUBROUTINE THAT INPUTS THE GIVEN DATA *****
170 PRINT : PRINT " ENTER THE OPERATION FREQUENCY f IN GHZ"
180 INPUT f
190 PRINT : PRINT " ENTER THE RATE THAT THE FREQUENCY CHANGES f0 IN GHZ/SEC"
200 INPUT f0
210 PRINT : PRINT " ENTER THE DURATION OF THE CHANGING FREQ. T IN ms"
220 INPUT T
230 PRINT : PRINT " ENTER THE TIME THE FREQ. TAKES TO RETURN TO ITS ORIGINAL VALUE Tr IN
 ms"
240 INPUT Tr
250 PRINT : PRINT " ENTER THE THE RANGE OF THE TARGET R IN Yards"
260 INPUT R
270 PRINT : PRINT " ENTER THE RELATIVE VELOCITY Ur IN ft/sec"
280 INPUT Ur
290 RETURN
300'*********************************************
310 REM : SUBROUTINE THAT PRINTS THE INPUT DATA
320'*********************************************
330 LPRINT : LPRINT " G I V E N "
340 LPRINT " ---------"
```

```
350 LPRINT : LPRINT "1. f=";f;"GHZ"TAB(19);" : OPERATING FREQUENCY"
360 LPRINT : LPRINT "2. f0=";f0;"GHZ/SEC"TAB(19);" : RATE THAT THE FREQUENCY CHANGE"
370 LPRINT : LPRINT "3. T=";T;"ms"TAB(19);" : DURATION OF THE CANGE"
380 LPRINT : LPRINT "4. Tr=";Tr;"ms"TAB(19);": TIME THE FREQ. NEEDS TO RETURN"
390 LPRINT TAB(17);"    TO ITS ORIGINAL VALUE"
400 LPRINT : LPRINT "5. R=";R;"Yards"TAB(19);" : RANGE OF THE TARGET"
410 LPRINT : LPRINT "6. Ur=";Ur;"ft/sec"TAB(19);" : RELATIVE VELOCITY"
420 RETURN
430'*****************************************************
440 REM : SUBROUTINE WHICH CALCULATE AND PRINTS PART a
450'*****************************************************
460 LET f0=f0*10^9          'CONVERTION FROM GHZ/SEC TO HZ/SEC
470 LET R=R*.914            'CONVERTION FROM Yards TO Meters
480 LET C=3*10^8             'm/sec
490 LET fr = f0*2*R/C        'FREQUENCY SHIFT
500 PRINT : PRINT : PRINT  " PART a:"
510 LPRINT : LPRINT : LPRINT   " PART a:"
520 LPRINT " -------"
530 PRINT : PRINT " 1(a). fr=";fr/1000;"KHZ";"  : FREQUENCY SHIFT"
540 LPRINT : LPRINT " 1(a). fr=";fr/1000;"KHZ";"  : FREQUENCY SHIFT"
550 RETURN
560'*****************************************************
570 REM : SUBROUTINE THAT CALCULATE AND PRINTS PART b
580'*****************************************************
590  LET f=f*10^9                    'CONVERTION FROM GHZ TO HZ
600  LET Ur=Ur*.305                  'CONVERTION FROM ft/sec TO m/s
610  LET l=C/f                       'WAVELENGTH IN meters
620  LET fd=2*Ur/l                    'DOPPLER SHIFT
630  LET dR=R*fd /fr                 'RANGE ERROR IN METERS
640  LET dR1=dR/100                   '% RANGE ERROR
650  PRINT : PRINT : PRINT " PART b:"
660  LPRINT : LPRINT : LPRINT " PART b:"
670  LPRINT " -------"
680  PRINT : PRINT " 1(b). fd=";fd;"HZ";"    : DOPPLER SHIFT"
690  LPRINT : LPRINT " 1(a). fd=";fd;"HZ";" DOPPLER SHIFT"
```

```
700 PRINT : PRINT "1(b). dR=";dR;"m";" OR";dR/.914;"Yards" ;"      : RANGE ERROR"
710 LPRINT :LPRINT "1(b). dR=";dR;"m";" OR";dR/.914;"Yards" ;"   : RANGE ERROR"
720 PRINT : PRINT "1(c). dR1=";dR1;"m";" OR";dR1/.914;"Yards" ;"     : % RANGE ERROR"
730 LPRINT : LPRINT "1(c). dR1=";dR1;"m";" OR";dR1/.914;"Yards" ;"  : % RANGE ERROR"
740 RETURN
```

## PROBLEM #4

GIVEN

1. f= 10.5 GHZ : OPERATING FREQUENCY
2. f0= 2 GHZ/SEC : RATE THAT THE FREQUENCY CHANGE
3. T= 990 ms : DURATION OF THE CANGE
4. Tr= 10 ms : TIME THE FREQ. NEEDS TO RETURN TO ITS ORIGINAL VALUE
5. R= 5000 Yards : RANGE OF THE TARGET
6. Ur= 25 ft/sec : RELATIVE VELOCITY

PART a:

1(a). fr= 60.93333 KHZ : FREQUENCY SHIFT

PART b:

1(a). fd= 533.75 HZ : DOPPLER SHIFT

1(b). dR= 40.03125 m OR 43.79787 Yards : RANGE ERROR

1(c). dR1= .4003125 m OR .4379787 Yards : % RANGE ERROR

```
10  PRINT : PRINT : PRINT  TAB(30); " PROBLEM #5"
20  LPRINT : LPRINT : LPRINT  TAB(30); " PROBLEM #5"
30  PRINT TAB(30); " ----------"
40  LPRINT TAB(30); " ----------"
50   GOSUB 90   : GOSUB 210
60   GOSUB 310  : GOSUB 410
70   GOTO 510
80 '*********************************************
90      REM : SUBROUTINE THAT INPUTS THE DATA
100*********************************************
110  PRINT : PRINT " ENTER THE OPERATING FREQ. f IN GHZ"
120  INPUT f
130  PRINT : PRINT " ENTER THE PULSE WIDTH t IN ms"
140  INPUT t
150  PRINT : PRINT " ENTER THE PULSE REPETITION FREQ. fp IN HZ"
160  INPUT fp
170  PRINT : PRINT " ENTER THE AIRCRAFT'S VELOCITY Uair IN Knots"
180  INPUT Uair
190  RETURN
200*********************************************
210  REM : SUBROUTINE THAT PRINTS THE INPUT DATA
220*********************************************
230  LPRINT : LPRINT : LPRINT " G I V E N"
240  LPRINT " ---------"
250  LPRINT : LPRINT " 1. f=";f;"GHZ"TAB(18); " : OPERATING FREQ."
260  LPRINT : LPRINT " 2. t=";t;"ms"TAB(18); " : PULSE WIDTH"
270  LPRINT :LPRINT " 3. fp=";fp;"HZ"TAB(18); " : PULSE REPETITION FREQ."
280  LPRINT :LPRINT " 4. Uair=";Uair;"Knots" ; " : AIRCRAFT'S VELOCITY"
290  RETURN
300*********************************************
310  REM : SUBROUTINE THAT CALCULATE AND PRINTS Uair
320*********************************************
330  LET f=f*10^9
340  LET C=3*10^8
350  LET l=C/f
```

```
360 LET U1b=1*fp/2
370 PRINT : PRINT : PRINT "U1b=";U1b;"m/s";" OR";U1b/.515;"Knots";"  : FIRST BLIND SPEED"
380 LPRINT : LPRINT : LPRINT "U1b=";U1b;"m/s";" OR";U1b/.515;"Knots";"  : FIRST BLIND
 SPEED"
390 RETURN
400**********************************************************
410   REM : SUBROUTINE THAT  FINDS IF THERE IS A DOPPLER AMBIGUITY
420**********************************************************
430  IF Ualr>U1b/.515   THEN   GOTO 440   ELSE 460
440  PRINT : PRINT " THERE IS A DOPPLER AMBIGUITY SINCE ";Ualr;"Knots"; ">";U1b/.515;"Knots"
450  LPRINT : LPRINT " THERE IS A DOPPLER AMBIGUITY SINCE ";Ualr;"Knots"; "
 >";U1b/.515;"Knots"
460  IF  Ualr<U1b/.515     THEN  GOTO 480   ELSE 470
470  IF  Ualr=U1b/.515     THEN  GOTO 480   ELSE 500
480  PRINT : PRINT " THERE ISN'T A DOPPLER AMBIGUITY SINCE ";Ualr;"Knots"; " < or
 =";U1b/.515;"Knots"
490  LPRINT : LPRINT " THERE ISN'T A DOPPLER AMBIGUITY SINCE ";Ualr;"Knots"; " < or
 =";U1b/.515;"Knots"
500  RETURN
510  PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N ?"
520  INPUT B$
530  IF LEFT$(B$,1)="Y" OR LEFT$(B$,1)="y"   THEN 30
540  END
```

PROBLEM#5

GIVEN

1. f= 9 GHZ : OPERATING FREQ.
2. t= 1 ms : PULSE WIDTH
3. fp= 1000 HZ : PULSE REPETITION FREQ.
4. Uair= 600 Knots : AIRCRAFT'S VELOCITY

Uib= 16.66667 m/s OR 32.36246 Knots : FIRST BLIND SPEED

*****THERE IS A DOPPLER AMBIGUITY SINCE 600 Knots > 32.36246 Knots*****

```
10  PRINT : PRINT TAB(30); " PROBLEM #6"
20  PRINT " ----------"
30  LPRINT : LPRINT TAB(30); "PROBLEM #6"
40  LPRINT TAB(30); "----------"
50  GOSUB 120  : GOSUB 430
60  GOSUB 520  : GOSUB 620
70  PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
80  INPUT E$
90  IF LEFT$(E$,1)="Y" OR LEFT$(E$,1)="y"  THEN 50
100 END
110*****************SUBROUTINES******************
120 '*       INPUTS THE DATA
130*********************************************
140 PRINT : PRINT " ENTER THE P.R.F fp IN HZ"
150 INPUT fp : PRINT : PRINT " 1. fp=";fp;"HZ"
160 PRINT : PRINT " ENTER THE CLUTTER SPECTRAL WIDTH Sc IN HZ"
170 INPUT Sc : PRINT : PRINT "2. Sc=";Sc;"HZ"
180 PRINT : PRINT " ENTER THE NUMBER OF THE DELAY LINE CANCELER"
190 PRINT " WITH OPTIMAL WEIGHTING N"
200 INPUT n : PRINT : PRINT " 3. N=";N
210 PRINT : PRINT " IS THE INPUT DATA CORRECT Y/N?"
220 INPUT A$
230 IF LEFT$(A$,1)="Y"  OR LEFT$(A$,1)="y"  THEN 410
240 PRINT : PRINT "WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
250 PRINT : PRINT " 1. THE P.R.F?"
260 PRINT : PRINT " 2. THE SPECTRAL CLUTTER WIDTH?"
270 PRINT : PRINT " 3. THE NUMBER OF THE DELAY LINE CANCELER?"
280 INPUT B$
290 IF B$="1"  THEN PRINT : PRINT " ENTER THE P.R.F fp IN HZ"
300 IF B$="1"  THEN INPUT fp : PRINT : PRINT " 2. fp=";fp;"HZ" : GOTO 350
310 IF B$="2"  THEN PRINT : PRINT " ENTER THE CLUTTER SPECTRAL WIDTH"
320 IF B$="2"  THEN INPUT Sc : PRINT : PRINT " 2. Sc=";Sc;"HZ" : GOTO 350
330 IF B$="3"  THEN PRINT : PRINT " ENTER THE NUMBER OF THE DELAY LINE CANCELER"
340 IF B$="3"  THEN INPUT N : PRINT : PRINT " 3. N=";N  : GOTO 350
350 PRINT : PRINT " IS EVERYTHING O.K NOW Y/N?"
```

```
360 INPUT C$
370 IF LEFT$(C$,1)="Y" OR LEFT$(C$,1)="y" THEN GOTO 410
380 PRINT : PRINT "WHAT DO YOU WANT TO CHANGE"
390 PRINT : PRINT "HIT ANY KEY IN YOUR KEYBOARD AND THE COMPUTER WILL WORK FOR YOU"
400 INPUT D$ : GOTO 250
410 RETURN
420'*********************************************
430 '*       PRINTS THE INPUT DATA                 *
440'*********************************************
450 LPRINT : LPRINT " G I V E N"
460 LPRINT " ---------"
470 LPRINT : LPRINT " 1. fp=";fp;"HZ" ,": P.R.F"
480 LPRINT : LPRINT " 2. Sc=";Sc;"HZ" ,": CLUTTER SPECTRAL WIDTH"
490 LPRINT : LPRINT " 3. N=";N ,": #OF DELAY LINE CANCELER WITH OPTIMAL WEIGHTING"
500 RETURN
510'*********************************************
520 '      CALCULATIONS                          *
530'*********************************************
540 PRINT : PRINT " FROM Fig. 4.25 (SKOLNIK Pg. 124) YOU CAN FIND THE IMROVEMENT FACTOR"
550 PRINT " SINCE YOU KNOW"
560 PRINT : PRINT " a. N=";N," : #OF DELAY LINE CANCELER"
570 PRINT "b. Sc/fp=";Sc/fp," : CLUTTER SPECTRAL WIDTH/RADAR P.R.F"
580 PRINT : PRINT " ENTER THE INTEGRATION IMR. FACTOR"
590 INPUT I
600 RETURN
610'*********************************************
620 '          PRINTS THE OUTPUT                  *
630'*********************************************
640 PRINT : PRINT : PRINT " OUTPUT"
650 LPRINT : LPRINT : LPRINT " OUTPUT"
660 LPRINT " ------"
670 PRINT : PRINT " 1. Sc/fp=";Sc/fp ," : CLUTTER SPECTRAL WIDTH/RADAR P.R.F"
680 LPRINT : LPRINT " 1. Sc/fp=";Sc/fp ," : CLUTTER SPECTRAL WIDTH/RADAR P.R.F"
690 PRINT : PRINT " 2. I=";I;"db" ," : INTEGRATION IMR. FACTOR"
700 LPRINT : LPRINT " 2. I=";I;"db" ,"          : INTEGRATION IMR. FACTOR"
```

```
710 RETURN
```

## PROBLEM#6

GIVEN

1. fp= 1000 HZ : P.R.F
2. Sc= 10 HZ : CLUTTER SPECTRAL WIDTH
3. N= 3 : #OF DELAY LINE CANCELER WITH OPTIMAL WEIGHTING

OUTPUT

1. Sc/fp= .01 : CLUTTER SPECTRAL WIDTH/RADAR P.R.F
2. I= 55 db : INTEGRATION IMR. FACTOR

```
10   PRINT : PRINT TAB(30); " PROBLEM #7"
20   PRINT TAB (30); " -----------"
30   REM ********** VARIABLES **********
40    LET C=3*10^8                    'm/s
50   LET PI=3.141593#
60   LET M=.4342945#
70    LET K=1.38*10^-23                'BOLTZMAN CONSTANT IN j/Deg
80    LET TO=290                       'STANDARD TEMPERATURE IN KELVIN
90    GOSUB 160  : GOSUB 2080 : GOSUB 810  : GOSUB 2260 : GOSUB 930  : GOSUB 2330
100  GOSUB 1160 : GOSUB 2480 : GOSUB 1760 : GOSUB 2640 : GOSUB 1960 : GOSUB 2730
110  PRINT : PRINT "DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
120   INPUT A$
130  IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y" THEN 20
140   END
150 '*******************************
160  '*      INPUTS THE DATA
170 '*******************************
180  PRINT : PRINT " ENTER THE PEAK POWER  Pp IN Kw"
190  INPUT Pp : PRINT : PRINT "  1. Pp=";Pp;"Kw"
200  PRINT : PRINT " ENTER THE P.R.F Fp IN HZ"
210  INPUT Fp : PRINT : PRINT "  2. Fp=";Fp;"HZ"
220  PRINT : PRINT " ENTER THE PULSE WIDTH T IN micsec"
230  INPUT T : PRINT : PRINT "  3. T=";T;"micsec"
240  PRINT : PRINT " ENTER THE FALSE ALARM TIME Tfa IN Hrs"
250  INPUT Tfa : PRINT : PRINT "  4. Tfa=";Tfa;"Hrs"
260  PRINT : PRINT " ENTER THE RECEIVER NOISE FIGURE F IN db"
270   INPUT F: PRINT : PRINT "  5. F=";F;"db"
280  PRINT : PRINT " ENTER THE TRANSMITTER FREQ. F0 IN MHZ "
290  INPUT F0 : PRINT : PRINT "  6. F0=";F0;"MHZ"
300  PRINT : PRINT " ENTER THE IF FREQ. Fif IN MHZ"
310  INPUT Fif : PRINT : PRINT "  7. Fif=";Fif;"MHZ"
320  PRINT : PRINT " ENTER THE IF BANDWIDTH Bif IN MHZ"
330  INPUT Bif : PRINT : PRINT "  8. Bif=";Bif;"MHZ"
340  PRINT : PRINT " ENTER THE ANTENNA POWER GAIN G IN db"
350  INPUT G : PRINT : PRINT "  9. G=";G;"db"
```

```
360 PRINT : PRINT " ENTER THE MINIMUM DETECTABLE SIGNAL M.D.S IN dbm"
370 INPUT M.D.S : PRINT : PRINT " 10. M.D.S=";M.D.S;"dbm"
380 PRINT :PRINT " IS THE INPUT DATA CORRECCT Y/N?"
390 INPUT B$
400 IF LEFT$(B$,1)="Y" OR LEFT$(B$,1)="y" THEN 790
410 PRINT : PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
420 PRINT : PRINT " 1. THE PEAK POWER?"
430 PRINT : PRINT " 2. THE P.R.F?"
440 PRINT : PRINT " 3. THE PULSE WIDTH?"
450 PRINT : PRINT " 4. THE FALSE ALARM TIME?"
460 PRINT :PRINT " 5. THE RECEIVER NOISE FIFURE?"
470 PRINT : PRINT " 6. THE TRANSMITTER FREQ.?"
480 PRINT : PRINT " 7. THE IF FREQ.?"
490 PRINT : PRINT " 8. THE IF BANDWIDTH?"
500 PRINT : PRINT " 9. ANTENNA POWER GAIN?"
510 PRINT : PRINT " 10. THE MINIMUM DET. SIGNAL?"
520 INPUT C$
530 IF C$="1" THEN PRINT : PRINT " ENTER THE PEAK POWER Pp IN Kw"
540 IF C$="1" THEN INPUT Pp : PRINT : PRINT " 1. Pp=";Pp;"Kw" : GOTO 730
550 IF C$="2" THEN PRINT : PRINT " ENTER THE P.R.F Fp IN HZ"
560 IF C$="2" THEN INPUT Fp : PRINT : PRINT " 2. Fp=";Fp;"HZ" : GOTO 730
570 IF C$="3" THEN PRINT : PRINT " ENTER THE PULSE WIDTH T IN micsec"
580 IF C$="3" THEN INPUT T : PRINT : PRINT " 3. T=";T;"micsec" : GOTO 730
590 IF C$="4" THEN PRINT : PRINT " ENTER THE FALSE ALARM TIME Tfa IN Hrs"
600 IF C$="4" THEN INPUT Tfa : PRINT : PRINT " 4. Tfa=";Tfa;"Hrs" : GOTO 730
610 IF C$="5" THEN PRINT : PRINT " ENTER THE RECEIVER NOISE FIGURE F IN db"
620 IF C$="5" THEN INPUT F: PRINT : PRINT " 5. F=";F;"db" : GOTO 730
630 IF C$="6" THEN PRINT : PRINT " ENTER THE TRANSMITTER FREQ. F0 IN MHZ "
640 IF C$="6" THEN INPUT F0 : PRINT : PRINT " 6. F0=";F0;"MHZ" : GOTO 730
650 IF C$="7" THEN PRINT : PRINT " ENTER THE IF FREQ. F1f IN MHZ"
660 IF C$="7" THEN INPUT F1f : PRINT : PRINT " 7. F1f=";F1f;"MHZ" : GOTO 730
670 IF C$="8" THEN PRINT : PRINT " ENTER THE IF BANDWIDTH B1f IN MHZ"
680 IF C$="8" THEN INPUT B1f : PRINT : PRINT " 8. B1f=";B1f;"MHZ" : GOTO 730
690 IF C$="9" THEN PRINT : PRINT " ENTER THE ANTENNA POWER GAIN G IN db"
700 IF C$="9" THEN INPUT G : PRINT : PRINT " 9. G=";G;"db" : GOTO 730
```

```
710  IF C$="10" THEN PRINT : PRINT " ENTER THE MINIMUM DETECTABLE SIGNAL M.D.S IN dbm"
720  IF C$="10" THEN INPUT M.D.S : PRINT : PRINT " 10. M.D.S=";M.D.S;"dbm" : GOTO 730
730  PRINT : PRINT " IS EVERYTHING O.K NOW?"
740  INPUT D$
750  IF LEFT$(D$,1)="Y" OR LEFT$(D$,1)="y" THEN GOTO 790
760  PRINT : PRINT " WHAT DO YOU WANT TO CHANGE AGAIN?"
770  PRINT : PRINT "HIT ANY KEY IN YOUR KEYBOARD AND EVERYTHING WILL WORK FOR YOU"
780  INPUT E$ : GOTO 420
790  RETURN
800 '*******************************************
810  ' CALCULATION FOR PART 1:
820 '*******************************************
830  PRINT : PRINT " NOW IS CALCULATED PART 1:"
840  LET Pp=Pp*10^3              'CONVERTION FROM Kw TO w
850  LET T=T*10^-6               'CONVERTION FORM msec TO sec.
860  LET Pav=Pp*Fp*T             'AVERAGE OUTPUT POWER
870  LET Pav=Pav/1000            'CONVERTION FROM w TO Kw
880  PRINT : PRINT : PRINT " PART 1:"
890  PRINT " -------"
900  PRINT : PRINT " 1. Pav=Pp*Fp*T=";Pav;"Kw";" : AVERAGE OUTPUT POWER"
910  RETURN
920 '*************************************
930  ' CALCULATION FOR PART 2:
940 '*************************************
950  PRINT : PRINT  " NOW IS CALCULATED PART 2:"
960  PRINT : PRINT : PRINT " PART 2:"
970  PRINT " -------"
980  LET Bif=Bif*10^6            'CONVERTION FROM MHZ TO HZ
990  LET Pn=K*T0*Bif             'NOISE POWER
1000 LET Pn1=10*M*LOG(Pn)        'CONVERTION FROM w TO dbw
1010 LET Pn2=Pn1+30              'CONVERTION FROM dbw TO dbm
1020 PRINT : PRINT " 2(a). Pn=K*T0*Bif=";Pn;"W";" OR ";CINT(Pn2);"dbm"; " : NOISE POWER"
1030 IF (Pn2>M.D.S) THEN GOTO 1090  ELSE 1040
1040 IF (Pn2<M.D.S) THEN GOTO 1100  ELSE 1050
1050 IF (Pn2=M.D.S) THEN GOTO 1110
```

```
1060 LET Tfa=Tfa*3600                    'CONVERTION FROM Hrs TO Sec.
1070 LET A=LOG(Tfa*Bif)
1080 LET A=10*M*LOG(A) : GOTO 1120              'CONVERTION FROM NUMERIC TO db
1090 PRINT : PRINT " 2(b). THE NOISE POWER IS GREATER THAN THE M.D.S" : GOTO 1060
1100 PRINT : PRINT " 2(b). THE NOISE POWER IS SMALLER THAN THE M.D.S" : GOTO 1060
1110 PRINT : PRINT " 2(b). THE NOISE POWER IS EQUAL THE M.D.S" : GOTO 1060
1120 PRINT : PRINT " 2(c). (Vt^2)/(2Y0)=In(Tfa*Bif)=";CSNG(A);"db"; " : R.M.S THRESHOLD POWER
TO NOISE RATIO"
1130 PRINT : PRINT TAB(55);"IF NO PULSE INTEGRATION IS PERFORMED"
1140 RETURN
1150'*****************************************
1160 ' CALCULATION FOR PART 3:
1170'*****************************************
1180 PRINT : PRINT " NOW IS CALCULATED PART 3:
1190 PRINT : PRINT " ENTER THE TARGET CROSS SECTION Sc IN SQ METERS"
1200 INPUT Sc
1210 PRINT : PRINT " ENTER THE PROBABILITY OF DETECTION Pd "
1220 INPUT Pd
1230 PRINT : PRINT " ENTER THE # OF PULSES THAT ARE INTEGRATED AFTER POST-DATECTION"
1240 INPUT n
1250 PRINT : PRINT " IS THE INPUT DATA CORRECCT Y/N?"
1260 INPUT F$
1270 IF LEFT$(F$,1)="Y" OR LEFT$(F$,1)="y" THEN 1460
1280 PRINT : PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
1290 PRINT : PRINT " 1. THE CROSS SECTION?"
1300 PRINT : PRINT " 2. THE PROBABILITY OF DETECTION?"
1310 PRINT : PRINT " 3. THE # OF INTEGRATED PULSES?"
1320 INPUT G$
1330 IF G$="1"  THEN PRINT : PRINT " ENTER THE CROSS SECTION Sc IN SQ. METERS"
1340 IF G$="1"  THEN INPUT Sc : GOTO 1390
1350 IF G$="2"  THEN PRINT : PRINT " ENTER THE PROBABILITY OF DETECTION Pd"
1360 IF G$="2"  THEN INPUT Pd : GOTO 1390
1370 IF G$="3"  THEN PRINT : PRINT " ENTER THE # OF PULSES TO BE INTEG. n"
1380 IF G$="3"  THEN INPUT n : GOTO 1390
1390 PRINT : PRINT " IS EVERYTHING O.K NOW?"
```

```
1400 INPUT H$
1410 IF LEFT$(H$,1)="Y" OR LEFT$(H$,1)="y" THEN GOTO 1460
1430 PRINT : PRINT " WHAT DO YOU WANT TO CHANGE AGAIN?"
1440 PRINT : PRINT "HIT ANY KEY IN YOUR KEYBOARD AND EVERYTHING WILL WORK FOR YOU"
1450 INPUT I$ : GOTO 1290
1460 LET Pfa=1/(Tfa*Bif)                    'PROBABILITY OF FALSE ALARM
1470 PRINT : PRINT " SINCE YOU KNOW THE PROBABILITY OF FALSE ALARM Pfa=";Pfa","
1480 PRINT : PRINT "THE PROBABILITY OF DETECTION Pd=";Pd;"FROM Fig. 2.7 (SKOLNIK Pg. 28)"
1490 PRINT : PRINT " YOU CAN FIND THE (S/N)1"
1500 PRINT : PRINT " ENTER THE (S/N)1 IN db"
1510 INPUT S1
1520 PRINT : PRINT " SINCE YOUR FLUCTUATION CASE IS CASE4 FROM Fig. 2.23 (SKOLNIK Pg.48)"
1530 PRINT : PRINT " YOU CAN FIND THE ADDITIONAL (S/N)1ad"
1540 PRINT : PRINT " ENTER THE ADDITIONAL (S/N)1ad IN db"
1550 INPUT S2
1560 LET S3=S1+S2
1570 PRINT : PRINT " FROM Fig. 2.24 (SKOLNIK Pg. 49) YOU CAN FIND THE INTEGR. IMR. FACTOR"
1580 PRINT : PRINT " ENTER THE INTEGR. IMR. FACTOR I1(n) IN db"
1590 INPUT I
1600 LET S4=S3-I
1610 PRINT : PRINT : PRINT " PART 3:"
1620 PRINT " -------"
1630 PRINT : PRINT " 3(a). Sc=";Sc;"sq. m"; " : TARGET CROSS SECTION"
1650 PRINT : PRINT " 3(b). Pd=";Pd; " : PROBABILITY OF DETECTION"
1660 PRINT : PRINT " 3(c). n=";n; " : #OF INTEGRATED PULSES"
1670 PRINT : PRINT " 3(d). YOUR MODEL IS IN CASE4";" : SWERLING MODEL"
1680 PRINT : PRINT " 3(e). Pfa=1/(Tfa*Bif)=";Pfa; " : PROBABILITY OF FALSE ALARM"
1690 PRINT : PRINT " 3(f). (S/N)1=";S1;"db"; " :(S/N)1 FOR ONE PULSE INTEGRATED FROM Fig 2.7"
1700 PRINT : PRINT " 3(g). (S/N)1ad=";S2;"db"; " ADDITIONAL (S/N) FROM Fig. 2.7"
1710 PRINT : PRINT " 3(h). (S/N)1tot=";S3;"db"; " : TOTAL (S/N) FROM Fig. 2.23"
1720 PRINT : PRINT " 3(i). I1(n)=";I;"db"; " : INTEGR. IMR. FACTOR FOR 30 PULSES FROM Fig. 2.24"
1730 PRINT : PRINT " 3(k). (S/N)30=(S/N)1tot/I1(n)=";S4;"db"; " : THE MIN. (S/N) REQUIRED TO
 ACHIEVEPd=0.5"
1740 RETURN
1750**************************************
```

```
1760 ' CALCULATIONS FOR PART 4:
1770'*****************************************
1780 PRINT : PRINT " NOW IS CALCULATED PART 4:"
1790 PRINT : PRINT " ENTER THE VALUE OF THE (S/N)min IN db"
1800 INPUT S
1810 PRINT : PRINT " ENTER THE TOTAL SYSTEM LOSSES Ls IN db"
1820 INPUT Ls
1830 LET F1=F/10 : F2=10^F1              'CONVERTION FROM db TO NUMERIC
1840 LET G1=G/10 : G2=10^G1              'CONVERTION FROM db TO NUMERIC
1850 LET Ls1=LS/10 : Ls2=10^Ls1          'CONVERTION FROM db TO NUMERIC
1860 LET F0=F0*10^6 : 1=C/F0
1870 LET S5=S/10 : S6=10^S5              'CONVERTION FROM db TO NUMERIC
1880LETR=(Pp*(G2^2)*(1^2)*Sc/(((4*PI)^3)*K*T0*F2*B1f*S6*Ls2))^(1/4)
1890 PRINT : PRINT : PRINT " PART 4:"
1900 PRINT " -------"
1910 PRINT : PRINT " 4(a). (S/N)min=";S;"db"
1920 PRINT : PRINT " 4(b). Ls=";Ls;"db"; " : TOTAL SYSTEM LOSSES"
1930 PRINT : PRINT " 4(c).
 R=(Pp*(G^2)*(1^2)*Sc/(((4*PI)^3)*(K*T0*F*B1f)*(S/N)min*Ls))^(1/4)=";CSNG(R/1000);"KM:";
 MAX.RANGE"
1940 RETURN
1950'*****************************************
1960 ' CALCULATIONS FOR PART 5:
1970'*****************************************
1980 PRINT : PRINT " NOW IS CALCULATED PART 5:"
1990 PRINT : PRINT " ENTER THE MIN. RADAR RANGE R1 IN KM"
2000 INPUT R1
2010 LET TR=2*R1*1000/C-T                'RECOVERY TIME
2020 PRINT : PRINT : PRINT " PART 5:"
2030 PRINT " -------"
2040 PRINT : PRINT " 5(a). R1=";R1;"KM"; " : MIN. RADAR RANGE"
2050 PRINT : PRINT " 5(b). TR=(2*R1*1000/C)-T=";TR*10^6;"micsec"; " : RECOVERY TIME"
2060 RETURN
2070'*****************************************
2080 ' SUBROUTINE THAT PRINTS THE INPUT DATA
```

```
2090'*******************************************
2100 LPRINT : LPRINT TAB(30); " PROBLEM #7"
2110 LPRINT TAB (30);" ----------"
2120 LPRINT : LPRINT : LPRINT " G I V E N "
2130 LPRINT " ---------"
2140 LPRINT : LPRINT " 1. Pp=";Pp;"Kw", " : PEAK POWER"
2150 LPRINT : LPRINT " 2. Fp=";Fp;"HZ", " : P.R.F"
2160 LPRINT : LPRINT " 3. T=";T;"micsec", " : PULSE WIDTH"
2170 LPRINT : LPRINT " 4. Tfa=";Tfa;"Hrs", " : FALSE ALARM TIME"
2180 LPRINT : LPRINT " 5. F=";F;"db", "          : RECEIVER NOISE FIGURE"
2190 LPRINT : LPRINT " 6. FO=";FO;"MHZ", " : TRANSMITTED FREQ."
2200 LPRINT : LPRINT " 7. Fif=";Fif;"MHZ", " : IF FREQUENCY"
2210 LPRINT : LPRINT " 8. Bif=";Bif;"MHZ", " : IF BANDWIDTH"
2220 LPRINT : LPRINT " 9. G=";G;"db", "          : ANTENNA POWER GAIN"
2230 LPRINT : LPRINT " 10. M.D.S=";M.D.S;"dbm", " : MIN. DETECTABLE SIGNAL"
2240 RETURN
2250'*******************************************
2260 ' SUBROUTINE THAT PRINTS PART 1:
2270'*******************************************
2280 LPRINT : LPRINT : LPRINT " PART 1:"
2290 LPRINT " -------"
2300 LPRINT : LPRINT " 1. Pav=Pp*Fp*T=";Pav;"Kw";" : AVERAGE OUTPUT POWER"
2310 RETURN
2320'*************************************
2330 ' SUBROUTINE THAT PRINTS PART 2:
2340'*************************************
2350 LPRINT : LPRINT : LPRINT " PART 2:"
2360 LPRINT " -------"
2370 LPRINT : LPRINT " 2(a). Pn=K*T0*Bif=";Pn;"W";" OR ";CINT(Pn2);"dbm"; " : NOISE POWER"
2380 IF (Pn2>M.D.S)  THEN GOTO 2410  ELSE 2390
2390 IF (Pn2<M.D.S)  THEN GOTO 2420  ELSE 2400
2400 IF (Pn2=M.D.S)  THEN GOTO 2430
2410 LPRINT : LPRINT " 2(b). THE NOISE POWER IS GREATER THAN THE M.D.S" : GOTO 2440
2420 LPRINT : LPRINT " 2(b). THE NOISE POWER IS SMALLER THAN THE M.D.S" : GOTO 2440
2430 LPRINT : LPRINT " 2(b). THE NOISE POWER IS EQUAL THE M.D.S"
```

```
2440 LPRINT :LPRINT " 2(c). (Vt^2)/(2Y0)=In(Tfa*Bif)=";CSNG(A);"db"; " : R.M.S THRESHOLD
 POWER TO NOISE RATIO"
2450 LPRINT :LPRINT TAB(55);"IF NO PULSE INTEGRATION IS PERFORMED"
2460 RETURN
2470**************************************
2480 ' SUBROUTINE THAT PRINTS PART 3:
2490**************************************
2500 LPRINT : LPRINT : LPRINT " PART 3:"
2510 LPRINT "-------"
2520 LPRINT : LPRINT " 3(a). Sc=";Sc;"sq. m"," :TARGET CROSS SECTION"
2530 LPRINT : LPRINT " 3(b). Pd=";Pd, " : PROBABILITY OF DETECTION"
2540 LPRINT : LPRINT " 3(c). n=";n, " : #OF INTEGRATED PULSES"
2550 LPRINT : LPRINT " 3(d). YOUR MODEL IS IN CASE4", " : SWERLING MODEL"
2560 LPRINT : LPRINT " 3(e). Pfa= 1/(Tfa*Bif)=";Pfa, " : PROBABILITY OF FALSE ALARM"
2570 LPRINT : LPRINT " 3(f). (S/N) 1=";S1;"db", " : (S/N) 1 FOR ONE PULSE INTEGRATED FROM Fig
 2.7"
2580 LPRINT : LPRINT " 3(g). (S/N) 1ad=";S2;"db", " : ADDITIONAL (S/N) FROM Fig. 2.7"
2590 LPRINT : LPRINT " 3(h). (S/N) 1tot=";S3;"db", " : TOTAL (S/N) FROM Fig. 2.23"
2600 LPRINT : LPRINT " 3(i). I1(n)=";I;"db", " : INTEGR. IMR. FACTOR FOR 30 PULSES FROM Fig.
 2.24"
2610 LPRINT : LPRINT " 3(k). (S/N)30=(S/N)tot/I1(n)=";S4;"db", " : THE MIN. (S/N) REQUIRED TO
 ACHIEVEPd=0.5"
2620 RETURN
2630**************************************
2640 ' SUBROUTINE THAT PRINTS PART 4:
2650**************************************
2660 LPRINT : LPRINT : LPRINT " PART 4:"
2670 LPRINT "-------"
2680 LPRINT : LPRINT " 4(a). (S/N)min=";S;"db"
2690 LPRINT : LPRINT " 4(b). Ls=";Ls;"db"; " : TOTAL SYSTEM LOSSES"
2700 LPRINT : LPRINT " 4(c).
 R=(Pp*(G^2)*(l^2)*Sc/(((4*PI)^3)*(K*TO*F*BIF)*(S/N)min*Ls))^(1/4)=";CSNG(R/1000);"KM:";
 MAX.RANGE"
2710 RETURN
2720**********************************
```

```
2730 ' SUBROUTINE THAT PRINTS PART 5:
2740'***********************************
2750 LPRINT : LPRINT : LPRINT " PART 5:"
2760 LPRINT "-------"
2770 LPRINT : LPRINT " 5(a). R1=";R1;"KM"; " : MIN. RADAR RANGE"
2780 LPRINT :LPRINT " 5(b). TR=(2*R1*1000/C)-T=";TR*10^6;"micsec"; " : RECOVERY TIME"
2790 RETURN
```

## PROBLEM*7

GIVEN

1. Pp= 200 Kw : PEAK POWER
2. Fp= 300 HZ : P.R.F
3. T= 60 micsec : PULSE WIDTH
4. Tfa= 2.2 Hrs : FALSE ALARM TIME
5. F= 6.5 db : RECEIVER NOISE FIGURE
6. F0= 400 MHZ : TRANSMITTED FREQ.
7. Fif= 120 MHZ : IF FREQUENCY
8. Bif= 1.25 MHZ : IF BANDWIDTH
9. G= 21 db : ANTENNA POWER GAIN
10. M.D.S=-115 dbm : MIN. DETECTABLE SIGNAL

PART 1 :

1. Pav=Pp*Fp*T= 3.6 Kw : AVERAGE OUTPUT POWER

PART 2 :

2(a). Pn=K*T0*Bif= 5.0025d-15 W OR -113 dbm : NOISE POWER

2(b). THE NOISE POWER IS GREATER THAN THE M.D.S

2(c). (Vt^2)/(2Y0)=ln(Tfa*Bif)= 13.6203 db : R.M.S THRESHOLD POWER TO NOISE RATIO IF NO PULSE INTEGRATION IS PERFORMED

PART 3 :

3(a). Sc= 1 sq. m :TARGET CROSS SECTION

3(b). Pd= .5 : PROBABILITY OF DETECTION

3(c). n= 30 : #OF INTEGRATED PULSES

3(d). YOUR MODEL IS IN CASE4 : SWERLING MODEL

3(e). Pfa=1/(Tfa*Bif)= 1E-10 : PROBABILITY OF FALSE ALARM

3(f). (S/N)1= 13.6 db : (S/N)1 FOR ONE PULSE INTEGRATED FROM Fig 2.7

3(g). (S/N)1ad= 1 db : ADDITIONAL (S/N)

3(h). (S/N)1tot= 14.6 db : TOTAL (S/N)

PART 4:

4(a). (S/N)min= 4 db

4(b). Ls= 1 db: TOTAL SYSTEM LOSSES

4(c).R=(Pp*(G^2)*(l^2)*Sc/(((4*PI)^3)*(K*T0*F*BIF)*(S/N)min*Ls))^(1/4)=59.7151KM:MAX
RANGE

PART 5:

5(a). R1= 10.5 KM: MIN. RADAR RANGE

5(b). TR=(2*R1*1000/C)-T= 10 micsec: RECOVERY TIME

```
10  PRINT : PRINT TAB(30); " PROBLEM #8"
20  PRINT TAB (30); " ----------"
30  LPRINT : LPRINT TAB(30); " PROBLEM #8"
40  LPRINT TAB (30); " ----------"
50  GOSUB 120 : GOSUB 490
60  GOSUB 650 : GOSUB 790
70  PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
80  INPUT A$
90  IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y" THEN 50
100 END
110 '*******************************
120 '*      INPUTS THE DATA          *
130 '*******************************
140 PRINT : PRINT " ENTER THE OPERATING FREQ. f IN GHZ"
150 INPUT f : PRINT : PRINT " 1. f=";f;"GHZ"
160 PRINT : PRINT " ENTER THE P.R.F fp IN HZ"
170 INPUT fp : PRINT : PRINT " 2. fp=";fp;"HZ"
180 PRINT : PRINT " FROM Fig. 13 (SKOLNIK Handbook Pg. 17-16) AND FOR CHAFF YOU CAN FIND"
190 PRINT " THE RANGE OF THE R.M.S VELOCITY SPREAD"
200 PRINT : PRINT " ENTER THE LOWER VALUE Su1 OF THE R.M.S VELOCITY SPREAD IN m/s"
210 INPUT Su1 : PRINT : PRINT " 3. Su1=";Su1;"m/s"
220 PRINT : PRINT " ENTER THE UPPER VALUE Su2 OF THE R.M.S VELOCITY SPREAD IN m/s"
230 INPUT Su2 : PRINT : PRINT " 4. Su2=";Su2;"m/s"
240 PRINT : PRINT " IS THE INPUT DATA CORRECCT Y/N?"
250 INPUT B$
260 IF LEFT$(B$,1)="Y" ORLEFT$(B$,1)="y" THEN 470
270 PRINT : PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
280 PRINT : PRINT " 1. THE OPERATING FREQ.?"
290 PRINT : PRINT " 2. THE P.R.F?"
300 PRINT : PRINT " 3. THE LOWER VALUE OF THE R.M.S VELOCITY SPREAD?"
310 PRINT : PRINT " 4. THE UPPER VALUE OF THE R.M.S VELOCITY SPREAD?"
320 INPUT C$
330 IF C$="1"  THEN PRINT : PRINT " ENTER THE OPERATING FREQ. f IN GHZ"
340 IF C$="1"  THEN INPUT f : PRINT : PRINT " 1. f=";f;"GHZ" : GOTO 410
350 IF C$="2"  THEN PRINT : PRINT " ENTER THE P.R.F fp IN HZ"
```

```
360  IF C$="2"  THEN INPUT fp : PRINT : PRINT " 2. fp=";fp;"HZ" : GOTO 410
370  IF C$="3"  THEN PRINT : PRINT " ENTER THE LOWER VALUE OF THE R.M.S VELOCITY SPREAD
 Su1 IN m/s"
380  IF C$="3"  THEN INPUT Su1 : PRINT : PRINT " 3. Su1=";Su1;"m/s" : GOTO 410
390  IF C$="4"  THEN PRINT : PRINT " ENTER THE UPPER VALUE OF THE R.M.S VELOCITY SPREAD
 Us2 IN m/s"
400  IF C$="4"  THEN INPUT Su2 : PRINT : PRINT " 4. Us2=";Us2;"m/s" : GOTO 410
410  PRINT : PRINT " IS EVERYTHING O.K NOW?"
420  INPUT D$
430  IF LEFT$(D$,1)="Y"  OR LEFT$(D$,1)="y" THEN GOTO 470
440  PRINT : PRINT " WHAT DO YOU WANT TO CHANGE AGAIN?"
450  PRINT : PRINT "HIT ANY KEY IN YOUR KEYBOARD AND EVERYTHING WILL WORK FOR YOU"
460  INPUT E$ : GOTO 280
470  RETURN
480'*********************************************
490  '        PRINTS THE INPUT DATA
500'*********************************************
510  PRINT : PRINT " G I V E N "
520  PRINT " ---------"
530  LPRINT : LPRINT " G I V E N"
540  LPRINT " ---------"
550  PRINT : PRINT " 1. f=";f;"GHZ"TAB(20);" : OPERATING FREQUENCY"
560 LPRINT : LPRINT " 1. f=";f;"GHZ"TAB(20);" : OPERATING FREQUENCY"
570  PRINT : PRINT " 2. fp=";fp;"HZ"TAB(20);" : P.R.F"
580  LPRINT : LPRINT " 2. fp=";fp;"HZ"TAB(20);" : P.R.F"
590  PRINT : PRINT " 3. Su1=";Su1;"m/s"TAB(20);" : LOWER VALUE OF THE R.M.S VELOCITY
 SPREAD"
600  LPRINT : LPRINT " 3. Su1=";Su1;"m/s"TAB(20);" : LOWER VALUE OF THE R.M.S VELOCITY
 SPREAD"
610  PRINT : PRINT " 4. Su2=";Su2;"m/s"TAB(20);" : UPPER VALUE OF THE R.M.S VELOCITY
 SPREAD"
620  LPRINT : LPRINT " 4. Su2=";Su2;"m/s"TAB(20);" : UPPER VALUE OF THE R.M.S VELOCITY
 SPREAD"
630  RETURN
640'*************************************
```

```
650 '      CALCULATIONS
660'*************************************
670  LET f=f*10^9                'convertion from GHz to Hz
680  LET C=3*10^8                'm/s
690  LET PI=3.14159
700  LET a1=C^2/(8*Su1^2)    'parameter dependent upon clutter
710  LET a2=C^2/(8*Su2^2)     'parameter dependent upon clutter
720 LET I2c1=a1^2*fp^4/(2*PI^4*f^4)  'imrovement factor
730  LET I2c2 =a2^2*fp^4/(2*PI^4*f^4)    'imrovement factor
740  LET M=.4342945#
750  LET I2c1=CINT(10*M*LOG(I2c1))              'convertion from numeric to db
760  LET I2c2=CINT(10*M*LOG(I2c2))               'convertion from numeric to db
770  RETURN
780'*************************************
790  '     PRINTS THE OUTPUT
800'*************************************
810  PRINT :PRINT " OUTPUT"
820  PRINT " ------"
830  LPRINT :LPRINT " OUTPUT"
840  LPRINT " ------"
850  PRINT :PRINT " 1. a1=C^2/(8*Su1^2)=";a1,": PARAMETER DEPENDENT UPON CLUTTER"
860  LPRINT :LPRINT " 1. a1=C^2/(8*Su1^2)=";a1,": PARAMETER DEPENDENT UPON CLUTTER"
870  PRINT :PRINT " 2. a2=C^2/(8*Su2^2)=";a2,": PARAMETER DEPENDENT UPON CLUTTER"
880  LPRINT :LPRINT " 2. a2=C^2/(8*Su2^2)=";a2,": PARAMETER DEPENDENT UPON CLUTTER"
890  PRINT :PRINT "3. I2c1=a1*fp^4/(2*PI^4*f^4)=";I2c1;"db",": IMPROVEMENT FACTOR"
900  LPRINT :LPRINT " 3. I2c1=a1*fp^4/(2*PI^4*f^4)=";I2c1;"db",": IMPROVEMENT FACTOR"
910  PRINT :PRINT "4. I2c2=a2*fp^4/(2*PI^4*f^4)=";I2c2;"db",": IMPROVEMENT FACTOR"
920  LPRINT :LPRINT " 4. I2c2=a2*fp^4/(2*PI^4*f^4)=";I2c2;"db",": IMPROVEMENT FACTOR"
930  PRINT :PRINT "THE IMROVEMENT FACTOR IS FROM";I2c1;"db";" TO";I2c2;"db"
940  LPRINT :LPRINT "THE IMROVEMENT FACTOR IS FROM";I2c1;"db";" TO";I2c2;"db"
950  RETURN
```

PROBLEM #8

GIVEN

1. f= 6 GHZ : OPERATING FREQUENCY
2. fp= 1000 HZ : P.R.F
3. Su1= .4 m/s : LOWER VALUE OF THE R.M.S VELOCITY SPREAD
4. Su2= 1 m/s : UPPER VALUE OF THE R.M.S VELOCITY SPREAD

OUTPUT

1. a1=C^2/(8*Su1^2)= 7.03125D+16 : PARAMETER DEPENDENT UPON CLUTTER
2. a2=C^2/(8*Su2^2)= 1.125D+16 : PARAMETER DEPENDENT UPON CLUTTER
3. I2c1=a1*fp^4/(2*PI^4*f^4)= 43 db : IMPROVEMENT FACTOR
4. I2c2=a2*fp^4/(2*PI^4*f^4)= 27 db : IMPROVEMENT FACTOR

**** THE IMROVEMENT FACTOR IS FROM 43 db TO 27 db ****

```
10  PRINT : PRINT TAB(30); " PROBLEM #9"
20  PRINT TAB (30); " -----------"
30  LPRINT : LPRINT TAB(30); " PROBLEM #9"
40  LPRINT TAB (30); " -----------"
50  GOSUB 120 : GOSUB 420
60  GOSUB 560 : GOSUB 630
70  PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
80  INPUT A$
90  IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y" THEN 50
100 END
110 '*******************************
120 '*      INPUTS THE DATA            *
130 '*******************************
140 PRINT : PRINT " ENTER THE MEAN FREQ. OF THE CLUTTER SPECTRUM IN HZ"
150 INPUT fe : PRINT : PRINT " 1. fe=";fe;"HZ"
160 PRINT : PRINT " ENTER THE P.R.F fp IN HZ"
170 INPUT fp : PRINT : PRINT " 2. fp=";fp;"HZ"
180 PRINT : PRINT " ENTER THE R.M.S CLUTTER SPREAD Sc IN HZ"
190 INPUT Sc : PRINT : PRINT " 3. Sc=";Sc;"HZ"
200 PRINT : PRINT " IS THE INPUT DATA CORRECCT Y/N?" '
210 INPUT B$
220 IF LEFT$(B$,1)="Y" ORLEFT$(B$,1)="y" THEN 400
230 PRINT : PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
240 PRINT : PRINT " 1. THE MEAN FREQ. OF THE CLUTTER SPECTRUM?"
250 PRINT : PRINT " 2. THE P.R.F?"
260 PRINT : PRINT "3. THE R.M.S CLUTTER SPREAD?"
270 INPUT C$
280 IF C$="1"  THEN PRINT : PRINT " ENTER THE MEAN FREQ. OF THE CLUTTER SPECTRUM fe IN
 HZ"
290 IF C$="1"  THEN INPUT fe : PRINT : PRINT " 1. fe=";fe;"HZ" : GOTO 340
300 IF C$="2"  THEN PRINT : PRINT " ENTER THE P.R.F fp IN HZ"
310 IF C$="2"  THEN INPUT fp : PRINT : PRINT " 2. fp=";fp;"HZ" : GOTO 340
320 IF C$="3"  THEN PRINT : PRINT " ENTER THE R.M.S CLUTTER SPREAD Sc IN HZ"
330 IF C$="3"  THEN INPUT Sc : PRINT : PRINT " 3. Sc=";Sc;"HZ" : GOTO 340
340 PRINT : PRINT " IS EVERYTHING O.K NOW?"
```

```
350  INPUT D$
360  IF LEFT$(D$,1)="Y"  OR LEFT$(D$,1)="y" THEN GOTO 400
370  PRINT : PRINT " WHAT DO YOU WANT TO CHANGE AGAIN?"
380  PRINT : PRINT "HIT ANY KEY IN YOUR KEYBOARD AND EVERYTHING WILL WORK FOR YOU"
390  INPUT E$ : GOTO 230
400  RETURN
410'*******************************************
420  '        PRINTS THE INPUT DATA
430'*******************************************
440  PRINT : PRINT " G I V E N "
450  PRINT " ---------"
460  LPRINT : LPRINT " G I V E N"
470  LPRINT " ---------"
480  PRINT : PRINT " 1. fe=";fe;"HZ"TAB(20);" : MEAN FREQUENCY OF THE CLUTTER SPECTRUM "
490  LPRINT : LPRINT " 1. fe=";fe;"HZ"TAB(20);" : MEAN FREQUENCY OF THE CLUTTER SPECTRUM "
500  PRINT : PRINT " 2. fp=";fp;"HZ"TAB(20);" : P.R.F"
510  LPRINT : LPRINT " 2. fp=";fp;"HZ"TAB(20);" : P.R.F"
520  PRINT : PRINT " 3. Sc=";Sc;"HZ"TAB(20);" : R.M.S CLUTTER SPREAD"
530  LPRINT : LPRINT " 3. Sc=";Sc;"HZ"TAB(20);" : R.M.S CLUTTER SPREAD"
540  RETURN
550'*************************************
560  '      CALCULATIONS
570'*************************************
590  LET F1=Sc/fp      'r.m.s clutter spread/pulse rep.freq.
600  LET F2=fe/fp      'mean freq. of the clutter spectrum/pulse rep. freq.
610  RETURN
620'*************************************
630  '  PRINTS THE OUTPUT
640'*************************************
650  PRINT : PRINT : PRINT " OUTPUT"
660  PRINT " ------"
670  LPRINT : LPRINT : LPRINT " OUTPUT"
680  LPRINT " ------"
690  PRINT : PRINT " 1. Sc/fp=";F1;" : R.M.S CLUTTER SPREAD/P.R.F"
700  PRINT : PRINT " 2. fe/fp="F2;" : MEAN FREQ. OF THE CLUTTER SPECTRUM/P R.F"
```

```
710 LPRINT :LPRINT " 1. Sc/fp=";F1;" : R.M.S CLUTTER SPREAD/P.R.F"
720 LPRINT : LPRINT " 2. fe/fp="F2;" : MEAN FREQ. OF THE CLUTTER SPECTRUM/P.R.F"
730 PRINT : PRINT " SINCE YOU KNOW THAT Sc/fp=";F1;" AND ";"fe/fp=";F2
740 PRINT : PRINT " FROM Fig. 4.34 (SKOLNIK Pg. 141) YOU CAN FIND THE IMR. FACTOR IN db"
750 PRINT : PRINT " ENTER THE VALUE OF THE IMR. FACTOR"
760 INPUT I
770 PRINT : PRINT " 3. I=";I;"db";" : REDUCTION OF THE IMR. FACTOR FOR THE NEAR IDEAL CASE,"
780 PRINT : PRINT TAB(16);"ASSUMING A THREE PULSE CANCELER"
790 LPRINT : LPRINT " 3. I=";I;"db";"  : REDUCTION OF THE IMR. FACTOR FOR THE NEAR IDEAL
 CASE,"
800 LPRINT : LPRINT TAB(19);"ASSUMING A THREE PULSE CANCELER"
810 RETURN
```

## PROBLEM#9

GIVEN

1. fe= 30 HZ : MEAN FREQUENCY OF THE CLUTTER SPECTRUM
2. fp= 300 HZ : P.R.F
3. Sc= 3 HZ : R.M.S CLUTTER SPREAD

OUTPUT

1. Sc/fp= .01 : R.M.S CLUTTER SPREAD/P.R.F
2. fe/fp= .1 : MEAN FREQ. OF THE CLUTTER SPECTRUM/P.R.F
3. I= 24 db : REDUCTION OF THE IMR. FACTOR FOR THE NEAR IDEAL CASE, ASSUMING A THREE PULSE CANCELER

```
10   PRINT : PRINT TAB(30); " PROBLEM #10"
20   PRINT TAB (30); " ----------"
30   GOSUB 100 : GOSUB 500
40   GOSUB 700 : GOSUB 880
50   PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
60   INPUT A$
70   IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y" THEN 30
80   END
90 '*******************************
100  '*      INPUTS THE DATA              *
110 '*******************************
120  PRINT : PRINT " ENTER THE OPERATING FREQ. f0 IN MHZ"
130  INPUT f0 : PRINT : PRINT " 1. f0=";f0;"MHZ"
140  PRINT : PRINT " ENTER THE SCAN ANGLE OFF,ANTENNA CENTER AXIS THs IN Deg."
150  INPUT THs : PRINT : PRINT " 2. THs=";THs;"Deg."
160  PRINT : PRINT " ENTER THE SEPARATION BETWEEN THE TWO ADJACENT ARRAY ELEMENTS d1
 IN cm"
170  INPUT d1 : PRINT : PRINT "3. d1=";d1;"cm"
180  PRINT : PRINT " ENTER THE DIAMETER OF THE PHASE ARRAY ANTENNA d IN m"
190  INPUT d : PRINT : PRINT " 4. d=";d;"m"
200  PRINT : PRINT " ENTER THE OFF CENTER ANGLE WHERE THE ANTENNA IS STEERED TH0 IN
 Deg."
210  INPUT TH0 : PRINT : PRINT "5. TH0=";TH0;"Deg."
220  PRINT : PRINT " IS THE INPUT DATA CORRECT Y/N?"
230  INPUT B$
240  IF LEFT$(B$,1)="Y" ORLEFT$(B$,1)="y" THEN 480
250  PRINT : PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
260  PRINT : PRINT " 1. THE OPERATING FREQ?"
270  PRINT : PRINT " 2. THE SCAN ANGLE OFF,ANTENNA CENTER AXIS?"
280  PRINT : PRINT " 3. THE SEPARATION BETWEEN THE TWO ADJACENT ARRAY ELEMENTS?"
290  PRINT : PRINT " 4. THE DIAMETER OF THE PHASE ARRAY ANTENNA?"
300  PRINT : PRINT " 5. THE OFF CENTER ANGLE WHERE THE ANTENNA IS STEERED?"
310  INPUT C$
320  IF C$="1"  THEN PRINT : PRINT " ENTER THE OPERATING FREQ.IN MHZ"
330  IF C$="1"  THEN INPUT f0 : PRINT : PRINT " 1. f0=";f0;"MHZ" : GOTO 420
340  IF C$="2"  THEN PRINT : PRINT " ENTER THE SCAN ANGLE OFF,ANTENNA CENTER AXIS THs IN
 Deg."
350  IF C$="2"  THEN INPUT THs : PRINT : PRINT " 2. THs=";THs;"Deg." : GOTO 420
360  IF C$="3"  THEN PRINT : PRINT " ENTER THE SEPARATION BETWEEN THE TWO ADJACENT
```

```
 ARRAY ELEMENTS d1 IN cm"
370  IF C$="3"  THEN INPUT d1 : PRINT : PRINT " 3. d1=";d1;"cm" : GOTO 420
380  IF C$="4"  THEN PRINT : PRINT " ENTER THE DIAMETER OF THE PHASE ARRAY ANTENNA d IN
 m"
390  IF C$="4"  THEN INPUT d : PRINT : PRINT " 4. d=";d;"m" : GOTO 420
400  IF C$="5"  THEN PRINT : PRINT " ENTER THE OFF CENTER ANGLE WHERE THE ANTENNA IS
 STEERED THO IN Deg."
410  IF C$="5"  THEN INPUT THO : PRINT : PRINT "5I THO=";THO;"Deg." : GOTO 420
420  PRINT : PRINT " IS EVERYTHING O.K NOW?"
430  INPUT D$
440  IF LEFT$(D$,1)="Y" OR LEFT$(D$,1)="y" THEN GOTO 480
450  PRINT : PRINT " WHAT DO YOU WANT TO CHANGE AGAIN?"
460  PRINT : PRINT "HIT ANY KEY IN YOUR KEYBOARD AND EVERYTHING WILL WORK FOR YOU"
470  INPUT E$ : GOTO 260
480  RETURN
490'*********************************************
500  '        PRINTS THE INPUT DATA
510'*********************************************
520  PRINT : PRINT " G I V E N"
530  PRINT " ---------"
540  PRINT : PRINT " 1. f0=";f0;"MHZ", " : OPERATING FREQUENCY"
550  PRINT : PRINT " 2. THs=";THs;"Deg.", " :  SCAN ANGLE OFF,ANTENNA CENTER AXIS"
560  PRINT : PRINT " 3. d1=";d1;"cm", "          : SEPARATION BETWEEN THE TWO ADJACENT
 ARRAYELEMENTS"
570  PRINT : PRINT " 4. d=";d;"m", "          : DIAMETER OF THE PHASE ARRAY ANTENNA"
580  PRINT : PRINT " 5. THO=";THO, "Deg.","  : THE OFF CENTER ANGLE WHERE THE ANTENNA IS
 STEERED"
590  LPRINT :LPRINT TAB(30);" PROBLEM # 10"
600 LPRINT TAB(30);" ----------"
610  LPRINT : LPRINT " G I V E N"
620  LPRINT " ---------"
630  LPRINT : LPRINT " 1. f0=";f0;"MHZ", " : OPERATING FREQUENCY"
640  LPRINT : LPRINT " 2. THs=";THs;"Deg.", " :  SCAN ANGLE OFF,ANTENNA CENTER AXIS"
650  LPRINT : LPRINT " 3. d1=";d1;"cm", "          : SEPARATION BETWEEN THE TWO ADJACENT
 ARRAYELEMENTS"
660  LPRINT : LPRINT " 4. d=";d;"m", "          : DIAMETER OF THE PHASE ARRAY ANTENNA"
670  LPRINT : LPRINT " 5. THO=";THO, "Deg.","  : THE OFF CENTER ANGLE WHERE THE ANTENNA IS
 STEERED"
680  RETURN
```

```
690'*************************************
700 '      CALCULATION FOR PART 1 :
710'*************************************
720 LET PI=3.141593#
730 LET C=3*10^8
740 LET f0=f0*10^6
750 LET l=C/f0
760 LET d1=d1/100
770 LET PHI=2*PI*(d1/l)*SIN(TH0*PI/180)
780  LET PHI1=180*PHI/PI            'Deg.
790'*************************************
800 '      CALCULATION FOR PART2 :
810'*************************************
820 LET K=.866
830  LET N=1
840 LET B.W=K*l/(N*d*(COS(TH0*PI/180)))
850  LET B.W1=180*B.W/PI              'Deg.
860 RETURN
870'*************************************
880 '      PRINTOUT FOR  PART 1 and PART 2
890'*************************************
900  PRINT : PRINT : PRINT " PART 1:"
910  PRINT " -----"
920  LPRINT : LPRINT : LPRINT " PART 1:
930  LPRINT " -----"
940  PRINT : PRINT " 1. PHI=2*PI*(d/l)*SIN(TH0)=";CSNG(PHI);"rad";" OR ";CSNG(PHI1);"Deg.";"
 : PHASE DIFFERENCE BETWEEN TWO ARRAY ELEMENTS"
950 LPRINT : LPRINT " 1. PHI=2*PI*(d/l)*SIN(TH0)=";CSNG(PHI);"rad";" OR ";CSNG(PHI1);"Deg.";"
  : PHASE DIFFERENCE BETWEEN TWO ARRAY ELEMENTS"
960  PRINT : PRINT : PRINT " PART 2:"
970  PRINT " ------"
980  LPRINT : LPRINT : LPRINT " PART 2:"
990  LPRINT " ------"
1000 PRINT : PRINT " 2. B.W=K*l/(N*d1*COS(TH0))=";CSNG(B.W);"rad";" OR ";CSNG(B.W1);"Deg.";
 "    : BEAMWIDTH AT 10 Deg. FOR THE SAME OUTPUT OF ARRAY ELEMENT"
1010 LPRINT : LPRINT " 2. B.W=K*l/(N*d1*COS(TH0))=";CSNG(B.W);"rad";" OR
 ";CSNG(B.W1);"Deg.";"    : BEAMWIDTH AT 10 Deg. FOR THE SAME OUTPUT OF ARRAY ELEMENT"
1020 RETURN
```

PROBLEM#10

GIVEN

1. f0= 1250 MHZ : OPERATING FREQUENCY
2. THs= 60 Deg. : SCAN ANGLE OF ANTENNA CENTER AXIS
3. d1= 20 cm : SEPARATION BETWEEN THE TWO ADJACENT ARRAY ELEMENTS
4. d= 29 m : DIAMETER OF THE PHASE ARRAY ANTENNA
5. TH0= 10 Deg. : THE OFF CENTER ANGLE WHERE THE ANTENNA IS STEERED

PART1:

1. PHI=2*PI*(d/1)*SIN(TH0)= .90922 rad OR 52.0945 Deg. : PHASE DIFFERENCE BETWEEN TWO ARRAY ELEMENTS

PART2:

2. B.W=K*1/(N*d1*COS(TH0))= 7.27746E-03 rad OR .416968 Deg. : BEAMWIDTH AT 10 Deg. FOR THE SAME OUTPUT OF ARRAY ELEMENT

```
10    PRINT : PRINT TAB(30) " PROBLEM #11 "
20    PRINT TAB(30); " ----------"
30    GOSUB 100 : GOSUB 840
40    GOSUB 1210
50    PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
60     INPUT D$
70    IF LEFT$(D$,1)="Y" OR LEFT$(D$,1)="y"   THEN 30
80     END
90  '**********************************
100   '          INPUTS THE DATA
110 '**********************************
120   PRINT : PRINT " ENTER THE ANTENNA GAIN Ga IN dbi"
130    INPUT Ga : PRINT : PRINT " 1. Ga=";Ga;"db"
140   PRINT : PRINT " ENTER THE PEAK POWER Pt IN Mw"
150    INPUT Pt : PRINT : PRINT " 2. Pt=";Pt;"Mw"
160   PRINT : PRINT " ENTER THE OPERATING FREQ. fo IN MHz"
170    INPUT fo : PRINT : PRINT " 3. fo=";fo;"MHz"
180   PRINT : PRINT " ENTER THE AMBIENT TEMPERATURE Ta IN KELVIN"
190    INPUT Ta : PRINT : PRINT " 4. Ta=";Ta;"KELVIN"
200   PRINT : PRINT " ENTER THE RECEIVER BANDWIDTH Bn IN MHz"
210    INPUT Bn : PRINT : PRINT " 5. Bn=";Bn;"MHz"
220   PRINT : PRINT " ENTER THE TARGET RADAR CROSS SECTION S IN sq.m"
230    INPUT S : PRINT : PRINT " 6. S=";S;"sq.m"
240   PRINT : PRINT " ENTER THE RECEIVER NOISE FIGURE F IN db"
250    INPUT F : PRINT : PRINT " 7. F=";F;"db"
260   PRINT : PRINT " ENTER THE P.R.F fp IN Hz"
270    INPUT fp : PRINT : PRINT " 8. fp=";fp;"Hz"
280   PRINT : PRINT " ENTER THE PULSE LENGTH t IN microsec."
290    INPUT t : PRINT : PRINT " 9. t=";t;"microsec."
300   PRINT : PRINT " ENTER THE INTEGRATION IMR. FACTOR Ii(n) IN db"
310    INPUT Ii : PRINT : PRINT " 10. Ii(n)=";Ii;"db"
320   PRINT : PRINT " ENTER THE PROBABILITY OF DETECTION Pd"
330    INPUT Pd : PRINT : PRINT " 11. Pd=";Pd
340   PRINT : PRINT " ENTER THE FALSE ALARM RATE Pfa"
350    INPUT Pfa : PRINT : PRINT " 12. Pfa=";Pfa
```

```
360  PRINT : PRINT " ENTER THE SYSTEM LOSSES Ls IN db"
370  INPUT Ls : PRINT : PRINT " 13. Ls=";Ls;"db"
380  PRINT : PRINT " IS THE INPUT DATA CORRECT Y/N?"
390  INPUT A$
400  IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y" THEN 820
410  PRINT : PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
420  PRINT : PRINT " 1. THE ANTENNA GAIN?"," 2. THE PEAK POWER?"
430  PRINT : PRINT " 3. THE OPERATING FREQ.?"," 4. THE AMBIENT TEMPERATURE?"
440  PRINT : PRINT " 5. THE RECEIVER BANDWIDTH?"," 6. THE TARGET CROSS SECTION?"
450  PRINT : PRINT " 7. THE RECEIVER NOISE FIGURE?"," 8. THE P.R.F?"
460  PRINT : PRINT " 9. THE PULSE LENGTH?"," 10. THE INTEGRATION IMR. FACTOR?"
470  PRINT : PRINT " 11. THE PROBABILITY OF DETECTION?"," 12. THE FALSE ALARM RATE?"
480  PRINT : PRINT " 13. THE SYSTEM LOSSES?"
490  INPUT C$
500  IF C$="1"  THEN PRINT : PRINT " ENTER THE ANTENNA GAIN Ga IN dbi"
510  IF C$="1"  THEN INPUT Ga : PRINT : PRINT " 1. Ga=";Ga;"db" : GOTO 760
520  IF C$="2"  THEN PRINT : PRINT " ENTER THE PEAK POWER Pt IN Mw"
530  IF C$="2"  THEN INPUT Pt : PRINT : PRINT " 2. Pt=";Pt;"Mw" : GOTO 760
540  IF C$="3"  THEN PRINT : PRINT " ENTER THE OPERATING FREQ. fo IN MHz"
550  IF C$="3"  THEN INPUT fo : PRINT : PRINT " 3. fo=";fo;"MHz" : GOTO 760
560  IF C$="4"  THEN PRINT : PRINT " ENTER THE AMBIENT TEMPERATURE Ta IN KELVIN"
570  IF C$="4"  THEN INPUT Ta : PRINT : PRINT " 4. Ta=";Ta;"KELVIN" : GOTO 760
580  IF C$="5"  THEN PRINT : PRINT " ENTER THE RECEIVER BANDWIDTH Bn IN MHz"
590  IF C$="5"  THEN INPUT Bn : PRINT : PRINT " 5. Bn=";Bn;"MHz" : GOTO 760
600  IF C$="6"  THEN PRINT : PRINT " ENTER THE TARGET RADAR CROSS SECTION S IN sq.m"
610  IF C$="6"  THEN INPUT S : PRINT : PRINT " 6. S=";S;"sq.m" : GOTO 760
620  IF C$="7"  THEN PRINT : PRINT " ENTER THE RECEIVER NOISE FIGURE F IN db"
630  IF C$="7"  THEN INPUT F : PRINT : PRINT " 7. F=";F;"db" : GOTO 760
640  IF C$="8"  THEN PRINT : PRINT " ENTER THE P.R.F fp IN Hz"
650  IF C$="8"  THEN INPUT fp : PRINT : PRINT " 8. fp=";fp;"Hz" : GOTO 760
660  IF C$="9"  THEN PRINT : PRINT " ENTER THE PULSE LENGTH t IN microsec."
670  IF C$="9"  THEN INPUT t : PRINT : PRINT " 9. t=";t;"microsec." : GOTO 760
680  IF C$="10"  THEN PRINT : PRINT " ENTER THE INTEGRATION IMR. FACTOR I1(n) IN db"
690  IF C$="10"  THEN INPUT I1 : PRINT : PRINT " 10. I1(n)=";I1;"db" : GOTO 760
700  IF C$="11"  THEN PRINT : PRINT " ENTER THE PROBABILITY OF DETECTION Pd"
```

```
710  IF C$="11"  THEN INPUT Pd : PRINT : PRINT " 11. Pd=";Pd : GOTO 760
720  IF C$="12"  THEN PRINT : PRINT " ENTER THE FALSE ALARM RATE Pfa"
730  IF C$="12"  THEN INPUT Pfa : PRINT : PRINT " 12. Pfa=";Pfa : GOTO 760
740  IF C$="13"  THEN PRINT : PRINT " ENTER THE SYSTEM LOSSES Ls IN db"
750  IF C$="13"  THEN INPUT Ls : PRINT : PRINT " 13. Ls=";Ls;"db" : GOTO 760
760  PRINT : PRINT " IS EVERYTHING O.K NOW?"
770  INPUT B$
780  IF LEFT$(B$,1)="Y" OR LEFT$(B$,1)="y"  THEN GOTO 820
790  PRINT : PRINT " WHAT DO YOU WANT TO CHANGE AGAIN?"
800  PRINT : PRINT " HIT ANY KEY IN YOUR KEYBOARD AND EVERYTHING WILL WORK FOR YOU
 MALAKA"
810  INPUT F$  : GOTO 410
820  RETURN
830 '*********************************
840  '      PRINTS THE INPUT DATA
850 '*********************************
860  LPRINT : LPRINT TAB(30); " PROBLEM #11"
870  LPRINT TAB(30); " ----------"
880  LPRINT : LPRINT " G I V E N"
890  LPRINT " ---------"
900  PRINT : PRINT " G I V E N"
910  PRINT " ---------"
920  PRINT : PRINT " 1. Ga=";Ga;"db" SPC(9); " : ANTENNA GAIN"
930  LPRINT : LPRINT " 1. Ga=";Ga;"db" SPC(9); " : ANTENNA GAIN"
940  PRINT : PRINT " 2. Pt=";Pt;"Mw" SPC(10); " : PEAK POWER"
950  LPRINT : LPRINT " 2. Pt=";Pt;"Mw" SPC(10); " : PEAK POWER"
960  PRINT : PRINT " 3. fo=";fo;"MHz" SPC(7); " : OPERATING FREQ."
970  LPRINT : LPRINT " 3. fo=";fo;"MHz" SPC(7); " : OPERATING FREQ."
980  PRINT : PRINT " 4. Ta=";Ta;"KELVIN" SPC(5); " : AMBIENT FREQ."
990  LPRINT : LPRINT " 4. Ta=";Ta;"KELVIN" SPC(5); " : AMBIENT FREQ."
1000 PRINT : PRINT " 5. Bn=";Bn;"MHz" SPC(9); " : RECEIVER BANDWIDTH"
1010 LPRINT : LPRINT " 5. Bn=";Bn;"MHz" SPC(9); " : RECEIVER BANDWIDTH"
1020 PRINT : PRINT " 6. S=";S;"sq.m" SPC(9); " : TARGET RADAR CROSS SECTION"
1030 LPRINT : LPRINT " 6. S=";S;"sq.m" SPC(9); " : TARGET RADAR CROSS SECTION"
1040 PRINT : PRINT " 7. F=";F;"db" SPC(10); " : RECEIVER NOISE FIGURE"
```

```
1050 LPRINT : LPRINT " 7. F=";F;"db" SPC(10); " : RECEIVER NOISE FIGURE"
1060 PRINT : PRINT " 8. fp=";fp;"Hz" SPC(8); " : P.R.F"
1070 LPRINT : LPRINT " 8. fp=";fp;"Hz" SPC(8); " : P.R.F"
1080 PRINT : PRINT " 9. t=";t;"microsec." SPC(4); " : PULSE LENGTH"
1090 LPRINT : LPRINT " 9. t=";t;"microsec." SPC(4); " : PULSE LENGTH"
1100 PRINT : PRINT " 10. Ii(n)=";Ii;"db" SPC(3); " : INTEGRATION IMR. FACTOR"
1110 LPRINT : LPRINT " 10. Ii(n)=";Ii;"db" SPC(3); " : INTEGRATION IMR. FACTOR"
1120 PRINT : PRINT " 11. Pd=";Pd SPC(10); " : PROBABILITY OF DETECTION"
1130 LPRINT : LPRINT " 11. Pd=";Pd SPC(10); " : PROBABILITY OF DETECTION"
1140 PRINT : PRINT " 12. Pfa=";Pfa; ": FALSE ALARM RATE"
1150 LPRINT : LPRINT " 12. Pfa=";Pfa; ": FALSE ALARM RATE"
1160 PRINT : PRINT " 13. Ls=";Ls;"db" SPC(9); " : SYSTEM LOSSES"
1180 LPRINT : LPRINT " 13. Ls=";Ls;"db" SPC(9); " : SYSTEM LOSSES"
1190 RETURN
1200'***********************************
1210 '  CALCULATION & PRINTOUT
1220'***********************************
1230 PRINT : PRINT : PRINT " OUTPUT"
1240 PRINT " ------"
1250 LPRINT : LPRINT : LPRINT " OUTPUT"
1260 LPRINT " ------"
1270 LET C=3*10^8
1280 LET fo=fo*10^6
1290 LET l=C/fo
1300 LET K=1.38*10^-23
1310 LET T=290
1320 LET PI=3.14159
1330 LET Pt=Pt*10^6
1340 LET Bn=Bn*10^6
1350 LET M=.4342945#
1360 PRINT : PRINT " FROM Fig. 2.7 (Skolnik Pg. 28) YOU CAN FIND THE (S/N)1 SINCE YOU KNOW
:"
1370 PRINT : PRINT " Pd=";Pd, "&","Pfa=";Pfa
1380 PRINT : PRINT " ENTER THE (S/N)1 SN IN db"
1390 INPUT SN
```

```
1400 LET Pt=10*M*LOG(Pt) : 1=10*M*LOG(1) : S=10*M*LOG(S)
1410 LET SUM1=Pt+2*Ga+2*1+11+S
1420 LET  Bn=10*M*LOG(Bn)
1430 LET A=(4*PI)^3 : A=10*M*LOG(A)
1440 LET B=K*T : B=10*M*LOG(B)
1450 LET SUM2=A+B+Bn+F+SN+Ls
1460 LET Rmax=(SUM1-SUM2)/4 : Rmax=Rmax/10:Rmax=10^Rmax
1470 PRINT :PRINT : PRINT " Rmax=";CSNG(Rmax/1000);"Km"; " or";
 CSNG(Rmax/(1000*1.85));" n. miles";"  :MAX.RADAR RANGE"
1480 LPRINT :LPRINT :LPRINT " Rmax=";CSNG(Rmax/1000);"Km"; " or";
 CSNG(Rmax/(1000*1.85));" n.miles"; "  :MAX. RADAR RANGE"
1490 RETURN
```

## PROBLEM # 11

GIVEN

1. Ga= 21 db : ANTENNA GAIN
2. Pt= 2 Mw : PEAK POWER
3. fo= 500 MHz : OPERATING FREQ.
4. Te= 62 KELVIN : AMBIENT FREQ.
5. Bn= 1 MHz : RECEIVER BANDWIDTH
6. S= 5 sq.m : TARGET RADAR CROSS SECTION
7. F= 10 db : RECEIVER NOISE FIGURE
8. fp= 300 Hz : P.R.F
9. t= 3 microsec. : PULSE LENGTH
10. I1(n)= 16.5 db : INTEGRATION IMR. FACTOR
11. Pd= .9 : PROBABILITY OF DETECTION
12. Pfa= .1E-12 : FALSE ALARM RATE
13. Ls= 6 db : SYSTEM LOSSES

OUTPUT

Rmax= 123.481 Km or 66.7464 n. miles : MAX. RADAR RANGE

```
10    PRINT : PRINT TAB(30) " PROBLEM #12 "
20    PRINT TAB(30); " ----------"
30    GOSUB 100  : GOSUB 1040 : GOSUB 1380 : GOSUB 1490
40    GOSUB 1690 : GOSUB 1840 : GOSUB 1950 : GOSUB 2110
50    PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
60     INPUT D$
70    IF LEFT$(D$,1)="Y" OR LEFT$(D$,1)="y"   THEN 20
80    END
90  '*********************************
100   '          INPUTS THE DATA
110 '*********************************
120   PRINT : PRINT " ENTER THE OPERATING FREQ. fo IN MHz"
130   INPUT fo : PRINT : PRINT "  1. fo=";fo;"MHz"
140   PRINT : PRINT " ENTER THE PEAK POWER Pt IN KW"
150   INPUT Pt : PRINT : PRINT " 2. Pt=";Pt;"KW"
160   PRINT : PRINT " ENTER THE P.R.F fp IN Hz"
170   INPUT fp : PRINT : PRINT " 3. fp=";fp;"Hz"
180   PRINT : PRINT " ENTER THE PULSE WIDTH t IN microsec."
190   INPUT t : PRINT : PRINT " 4. t=";t;"microsec."
200   PRINT : PRINT " ENTER THE ANTENNA SCAN RATE Wm IN Hz"
210   INPUT Wm : PRINT : PRINT " 5. Wm=";Wm;"Hz"
220   PRINT : PRINT " ENTER THE AZIMUTH BEAMWIDTH A.B IN deg."
230   INPUT A.B : PRINT : PRINT " 6. A.B=";A.B;"deg."
240   PRINT : PRINT " ENTER THE ANTENNA GAIN Ga IN db"
250   INPUT Ga : PRINT : PRINT " 7. Ga=";Ga;"db"
260   PRINT :PRINT " ENTER THE RECEIVER NOISE BANDWIDTH Bn IN MHz"
270   INPUT Bn : PRINT : PRINT " 8. Bn=";Bn;"MHz"
280   PRINT : PRINT " ENTER THE RECEIVER NOISE FIGURE F IN db"
290   INPUT F : PRINT : PRINT " 9. F=";F;"db"
300   PRINT : PRINT " ENTER THE SYSTEM LOSSES Ls IN db"
310   INPUT Ls : PRINT : PRINT "  10. Ls=";Ls;"db"
320   PRINT : PRINT " ENTER THE FALSE ALARM TIME Tfa IN days"
330   INPUT Tfa : PRINT : PRINT " 11. Tfa=";Tfa;"days"
340   PRINT : PRINT " ENTER THE ANTENNA NOISE TEMPERATURE Ta IN KELVIN"
350   INPUT Ta : PRINT : PRINT "  12. Ta=";Ta;"Kelvin"
```

```
420  PRINT : PRINT " IS THE INPUT DATA CORRECT Y/N?"
430  INPUT A$
440  IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y" THEN 1020
450  PRINT : PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
460  PRINT : PRINT " 1. THE OPERATING FREQ.?"
470  PRINT : PRINT " 2. THE PEAK POWER?"
480  PRINT : PRINT " 3. THE P.R.F?"
490  PRINT : PRINT " 4. THE PULSE WIDTH?"
500  PRINT : PRINT " 5. THE ANTENNA SCAN RATE?"
510  PRINT : PRINT " 6. THE AZIMUTH BEAMWIDTH?"
520  PRINT : PRINT " 7. THE ANTENNA GAIN?"
530  PRINT : PRINT " 8. THE RECEIVER NOISE BANDWIDTH?"
540  PRINT : PRINT " 9. THE RECEIVER NOISE FIGURE?"
550  PRINT : PRINT " 10. THE SYSTEM LOSSES?"
560  PRINT : PRINT " 11. THE FALSE ALARM TIME?"
570  PRINT : PRINT " 12. THE ANTENNA NOISE TEMPERATURE?"
580  INPUT C$
590  IF C$="1" THEN PRINT : PRINT " ENTER THE OPERATING FREQ. fo IN MHz"
600  IF C$="1" THEN INPUT fo : PRINT : PRINT " 1. fo=";fo;"MHz" : GOTO 820
610  IF C$="2" THEN PRINT : PRINT " ENTER THE PEAK POWER Pt IN KW"
620  IF C$="2" THEN INPUT Pt : PRINT : PRINT " 2. Pt=";Pt;"KW" : GOTO 820
630  IF C$="3" THEN PRINT : PRINT " ENTER THE P.R.F fp IN Hz"
640  IF C$="3" THEN INPUT fp : PRINT : PRINT " 3. fp=";fp;"Hz" : GOTO 820
650  IF C$="4" THEN PRINT : PRINT " ENTER THE PULSE WIDTH t IN microsec."
660  IF C$="4" THEN INPUT t : PRINT : PRINT " 4. t=";t;"microsec." : GOTO 820
670  IF C$="5" THEN PRINT : PRINT " ENTER THE ANTENNA SCAN RATE Wm IN Hz"
680  IF C$="5" THEN INPUT Wm : PRINT : PRINT " 5. Wm=";Wm;"Hz" : GOTO 820
690  IF C$="6" THEN PRINT : PRINT " ENTER THE AZIMUTH BEAMWIDTH A.B IN deg."
700  IF C$="6" THEN INPUT A.B : PRINT : PRINT " 6. A.B=";A.B;"deg." : GOTO 820
710  IF C$="7" THEN PRINT : PRINT " ENTER THE ANTENNA GAIN Ge IN db"
720  IF C$="7" THEN INPUT Ge : PRINT : PRINT " 7. Ge=";Ge;"db" : GOTO 820
730  IF C$="8" THEN PRINT : PRINT " ENTER THE RECEIVER NOISE BANDWIDTH Bn IN MHz"
740  IF C$="8" THEN INPUT Bn : PRINT : PRINT " 8. Bn=";Bn;"MHz" : GOTO 820
750  IF C$="9" THEN PRINT : PRINT " ENTER THE RECEIVER NOISE FIGURE F IN db"
760  IF C$="9" THEN INPUT F : PRINT : PRINT " 9. F=";F;"db" : GOTO 820
```

```
770   IF C$="10"  THEN PRINT : PRINT " ENTER THE SYSTEM LOSSES Ls IN db"
780   IF C$="10"  THEN INPUT Ls : PRINT : PRINT " 10. Ls=";Ls;"db" : GOTO 820
780   IF C$="11"  THEN PRINT : PRINT " ENTER THE FALSE ALARM TIME Tfa IN days"
790   IF C$="11"  THEN INPUT Tfa : PRINT : PRINT " 11. Tfa=";Tfa;"days" : GOTO 820
800   IF C$="12"  THEN PRINT : PRINT " ENTER THE ANTENNA NOISE TEMPERATURE Ta IN
 KELVIN"
810   IF C$="12"  THEN INPUT Ta : PRINT : PRINT " 12. Ta=";Ta;"Kelvin" : GOTO 820
820   PRINT : PRINT " IS EVERYTHING O.K NOW?"
970   INPUT B$
980   IF LEFT$(B$,1)="Y"  OR LEFT$(B$,1)="y" THEN GOTO 1020
990   PRINT : PRINT " WHAT DO YOU WANT TO CHANGE AGAIN?"
1000  PRINT : PRINT " HIT ANY KEY IN YOUR KEYBOARD AND EVERYTHING WILL WORK FOR YOU
 MALAKA"
1010  INPUT F$  : GOTO 460
1020  RETURN
1030'**********************************
1040  '       PRINTS THE INPUT DATA
1050'**********************************
1060  LPRINT : LPRINT TAB(30); " PROBLEM #12"
1070  LPRINT TAB(30); " ------------"
1080  LPRINT : LPRINT " G I V E N"
1090  LPRINT " ---------"
1100  PRINT : PRINT " G I V E N"
1110  PRINT " ---------"
1120  PRINT : PRINT " 1. fo=";fo;"MHz" SPC(7); " : OPERATING FREQ."
1130  LPRINT : LPRINT " 1. fo=";fo;"MHz" SPC(7); " : OPERATING FREQ."
1140  PRINT : PRINT " 2. Pt=";Pt;"KW" SPC(9); " : PEAK POWER"
1150  LPRINT : LPRINT " 2. Pt=";Pt;"KW" SPC(9); " : PEAK POWER"
1160  PRINT : PRINT " 3. fp=";fp;"Hz" SPC(9) " : P.R.F"
1170  LPRINT : LPRINT " 3. fp=";fp;"Hz" SPC(9) " : P.R.F"
1180  PRINT : PRINT " 4. t=";t;"microsec" SPC(4); " : PULSE WIDTH"
1190  LPRINT : LPRINT " 4. t=";t;"microsec" SPC(4); " : PULSE WIDTH"
1200  PRINT : PRINT " 5. Wm=";Wm;"Hz" SPC(10); " : ANTENNA SCAN RATE"
1210  LPRINT : LPRINT " 5. Wm=";Wm;"Hz" SPC(10); " : ANTENNA SCAN RATE"
1220  PRINT : PRINT " 6. A.B=";A.B;"deg." SPC(6); " : AZIMUTH BEAMWIDTH"
```

```
1230 LPRINT : LPRINT " 6. A.B=";A.B;"deg." SPC(6);" : AZIMUTH BEAMWIDTH"
1240 PRINT : PRINT " 7. Ge=";Ge;"db" SPC(10);" : ANTENNA GAIN"
1250 LPRINT : LPRINT " 7. Ge=";Ge;"db" SPC(10);" : ANTENNA GAIN"
1260 PRINT : PRINT " 8. Bn=";Bn;"MHZ" SPC(10);" : RECEIVER NOISE BANDWIDTH"
1270 LPRINT : LPRINT " 8. Bn=";Bn;"MHZ" SPC(10);" : RECEIVER NOISE BANDWIDTH"
1280 PRINT : PRINT " 9. F=";F;"db"; SPC(9);" : RECEIVER NOISE FIGURE"
1290 LPRINT : LPRINT " 9. F=";F;"db"; SPC(9);" : RECEIVER NOISE FIGURE"
1300 PRINT : PRINT " 10. Ls=";Ls;"db" SPC(10);" : SYSTEM LOSSES"
1310 LPRINT : LPRINT " 10. Ls=";Ls;"db" SPC(10);" : SYSTEM LOSSES"
1320 PRINT : PRINT " 11. Tfa=";Tfa SPC(11);" : FALSE ALARM TIME"
1330 LPRINT : LPRINT " 11. Tfa=";Tfa SPC(11);" : FALSE ALARM TIME"
1340 PRINT : PRINT " 12. Te=";Te;"Kelvin" SPC(5);" : ANTENNA NOISE TEMPERATURE"
1350 LPRINT : LPRINT " 12. Te=";Te;"Kelvin" SPC(5);" : ANTENNA NOISE TEMPERATURE"
1360 RETURN
1370'************************************
1380 ' CALCULATION & PRINTOUT FOR PART a:
1390'************************************
1400 PRINT : PRINT : PRINT " PART a:"
1410 PRINT " -------"
1420 LPRINT : LPRINT : LPRINT " PART a:"
1430 LPRINT " -------"
1440 LET Ts=60/Wm : n=CSNG(A.B*Ts*fp/360)
1450 PRINT : PRINT " n=";n;" : # OF HITS PER SCAN"
1460 LPRINT : LPRINT " n=";n;" : # OF HITS PER SCAN"
1470 RETURN
1480'************************************
1490 ' CALCULATION & PRINTOUT FOR PART b:
1500'************************************
1510 PRINT : PRINT : PRINT " PART b:"
1520 PRINT " -------"
1530 LPRINT : LPRINT : LPRINT " PART b:"
1540 LPRINT " -------"
1550 LET Tfa=Tfa*24*3600 : Bn=Bn*10^6 : Pfa=CSNG(1/(Tfa*Bn))
1560 PRINT : PRINT " ENTER THE PROBABILITY OF DETECTION Pd"
1570 INPUT Pd
```

```
1580  PRINT : PRINT " FROM FIG. 2.7 (Skolnik Pg. 28) YOU CAN FIND THE (S/N)1 SINCE THE :"
1590  PRINT :PRINT " Pfa=";Pfa,"&","Pd=";Pd
1600  INPUT SN
1610  PRINT : PRINT " a. Pd=";Pd;" : PROBABILITY OF DETECTION"
1620  PRINT : PRINT " b. Pfa=";Pfa;" : PROBABILITY OF FALSE ALARM"
1630  PRINT : PRINT " c. (S/N)1 =";SN;"db"; " : (S/N) FOR SINGLE PULSE"
1640  LPRINT :LPRINT " a. Pd=";Pd;" : PROBABILITY OF DETECTION"
1650  LPRINT : LPRINT " b. Pfa=";Pfa;" : PROBABILITY OF FALSE ALARM"
1660  LPRINT : LPRINT " c. (S/N)1 =";SN;"db"; " : (S/N) FOR SINGLE PULSE"
1670  RETURN
1680'*************************************
1690  ' CALCULATION & PRINTOUT FOR PART c:
1700'*************************************
1710  PRINT : PRINT : PRINT " PART c:"
1720  PRINT " -------"
1730  LPRINT : LPRINT : LPRINT " PART c:"
1740  LPRINT " -------"
1750  PRINT : PRINT " FROM Fig. 2.8(a), (Skolnik Pg. 31) YOU CAN FIND THE INTEGRATION
 IMROVEMENT"
1760  PRINT :PRINT " FOR INCOHERENT INTEGRATION OF n=";"n";"PULSES"
1770  PRINT : PRINT " ENTER THE INTEGRATION IMR. I1(n)"
1780  INPUT I1
1790 I11=CSNG(10*.4342945**LOG(I1))
1800  PRINT : PRINT " I1(n)=";I1;"numeric";" or";I11;"db"
1810  LPRINT :LPRINT " I1(n)=";I1;"numeric";" or";I11;"db"
1820  RETURN
1830'*************************************
1840  ' CALCULATION & PRINTOUT FOR PART d:
1850'*************************************
1860  PRINT : PRINT : PRINT " PART d:"
1870  PRINT " -------"
1880  LPRINT : LPRINT : LPRINT " PART d:"
1881  LPRINT " -------"
1890  LET K=1.38*10^-23 : T0=290: F=F/10 : F=10^F
1900 LET MDS=K*T0*F*Bn :MDS1=CSNG(10*.4342945**LOG(MDS))
```

```
1910 PRINT :PRINT " M.D.S=";MDS1;"dbw"; " : MINIMUM DETECTABLE SIGNAL POWER"
1920 LPRINT :LPRINT "M.D.S=";MDS1;"dbw"; " : MINIMUM DETECTABLE SIGNAL POWER"
1930 RETURN
1940'************************************
1950 ' CALCULATION & PRINTOUT FOR PART e & f:
1960'************************************
1970 PRINT : PRINT : PRINT " PART e & f:"
1980 PRINT " -----------"
1990 LPRINT : LPRINT : LPRINT " PART e & f:"
1991 LPRINT " -----------"
2000 LET Pt=Pt*10^3 :Pt1=CINT(10*.4342945**LOG(Pt))
2010 LET Peff=Pt1+Ga
2020 LET PI=3.14159 : Ga=Ga/10 :Ga=10^Ga
2030 LET C=3*10^8 : fo=fo*10^6 : l=C/fo
2040 LET Ae=CSNG(l^2*Ga/(4*PI))
2050 PRINT : PRINT "e. Peff=";Peff;"dbw"; " : PEAK EFFECTIVE RADIATED POWER"
2060 PRINT : PRINT " f. Ae=";Ae;"sq.m"; " : EEFFECTIVE AREA OF THE ANTENNA "
2070 LPRINT : LPRINT "e. Peff=";Peff;"dbw"; " : PEAK EFFECTIVE RADIATED POWER"
2080 LPRINT : LPRINT " f. Ae=";Ae;"sq.m"; " : EEFFECTIVE AREA OF THE ANTENNA "
2090 RETURN
2100'************************************
2110 ' CALCULATION & PRINTOUT FOR PART g:
2130'************************************
2140 PRINT : PRINT : PRINT " PART g:"
2150 PRINT " -------"
2160 LPRINT : LPRINT : LPRINT " PART g:"
2161 LPRINT " -------"
2170 PRINT : PRINT " ENTER THE CROSS SECTION OF THE NON FLUCTUATING TARGET RCS IN db"
2180 INPUT RCS
2190 LET Ls=Ls/10 :Ls=10^Ls :Te=(F-1)*T0 :RCS=RCS/10 :RCS=10^-RCS
2200 LET SN=SN/10 : SN=10^SN
2210LETRmax=CSNG((Pt*Ga*Ae*RCS*l1/((4*PI)^2*K*(Ta+Te)*Bn*SN*Ls))^(1/4))
2220 PRINT : PRINT " Rmax=";Rmax/1000;"KM"; " : MAXIMUM RANGE"
2230 LPRINT : LPRINT " Rmax=";Rmax/1000;"KM"; " : MAXIMUM RANGE"
2240 RETURN
```

## PROBLEM # 12

GIVEN

1. fo= 5600 MHz : OPERATING FREQ.
2. Pt= 200 KW : PEAK POWER
3. fp= 625 Hz : P.R.F
4. t= 1.4 microsec : PULSE WIDTH
5. Wm= 16 Hz : ANTENNA SCAN RATE
6. A.B= 1.5 deg. : AZIMUTH BEAMWIDTH
7. Ga= 33 db : ANTENNA GAIN
8. Bn= 1 MHZ : RECEIVER NOISE BANDWIDTH
9. F= 9.88 db : RECEIVER NOISE FIGURE
10. Ls= 5 db : SYSTEM LOSSES
11. Tfa= 2 : FALSE ALARM TIME
12. Ta= 75 Kelvin : ANTENNA NOISE TEMPERATURE

PART a:

n= 9.76563 : # OF HITS PER SCAN

PART b:

a. Pd= .95 : PROBABILITY OF DETECTION

b. Pfa= 5.78704D-12 : PROBABILITY OF FALSE ALARM

c. (S/N)1= 16 db : (S/N) FOR SINGLE PULSE

PART c:

11(n)= 7 numeric or 8.45098 db

PART d:

M.D.S=-134.097 dbw : MINIMUM DETECTABLE SIGNAL POWER

PART e & f:

e. Peff= 86 dbw : PEAK EFFECTIVE RADIATED POWER

PART g:

Rmax= 36.5283 KM : MAXIMUM RANGE

```
10    PRINT : PRINT TAB(30); " PROBLEM #13 "
20    PRINT TAB(30); " ----------"
30    GOSUB 100   : GOSUB 710  : GOSUB 990
40    GOSUB 1110  : GOSUB 1240 : GOSUB 1350
50    PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
60    INPUT D$
70    IF LEFT$(D$,1)="Y" OR LEFT$(D$,1)="y"  THEN 30
80    END
90  '**********************************
100   '          INPUTS THE DATA
110 '**********************************
120   PRINT : PRINT " ENTER THE OPERATING FREQ. fo IN GHz"
130   INPUT fo : PRINT : PRINT "  1. fo=";fo;"GHz"
140   PRINT : PRINT "ENTER THE RADAR CROSS SECTION OF THE VEHICLES RCS IN dbsm"
150   INPUT RCS : PRINT : PRINT " 2. RCS=";RCS;"dbsm"
160   PRINT : PRINT " ENTER THE TRAVELING SPEED OF THE VEHICLES U IN mi/hrs"
170   INPUT U : PRINT : PRINT " 3. U=";U;"mi/hrs"
180   PRINT : PRINT " ENTER THE RANGE THE RADAR WILL DETECT THE VEHICLES R IN MILES"
190   INPUT R : PRINT : PRINT " 4. R=";R;"miles"
200   PRINT :PRINT " ENTER THE (S/N) REQUIRED AT THE OUTPUT OF THE IF AMPLIFIER SNout IN
 db"
210   INPUT SNout : PRINT : PRINT " 5. (S/N)out=";SNout;"db"
220   PRINT : PRINT " ENTER THE RECEIVER NOISE FIGURE F IN db"
230   INPUT F : PRINT : PRINT " 6. F=";F;"db"
240   PRINT : PRINT " ENTER THE PLUMBING LOSSES Lp IN db"
250   INPUT Lp : PRINT : PRINT " 7. Lp=";Lp;"db"
260   PRINT : PRINT " ENTER THE NOISE TEMPERATURE OF THE RECEIVER Te IN KELVIN"
270   INPUT Te : PRINT : PRINT " 8. Te=";Te;"Kelvin"
280   PRINT : PRINT " ENTER THE GAIN Gt OF THE TRANSMIT ANTENNA & Gr OF THE RECEIVE
 ANTENNA IN db"
290   INPUT Gr,Gt : PRINT : PRINT " 9. Gt=";Gt, "Gr=";Gr;"db"
300   PRINT : PRINT " IS THE INPUT DATA CORRECT Y/N?"
310   INPUT A$
320   IF LEFT$(A$,1)="Y"  OR LEFT$(A$,1)="y"  THEN 690
330   PRINT : PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
```

```
340  PRINT : PRINT " 1. THE OPERATING FREQ.?"
350  PRINT : PRINT " 2. THE VEHICLES RADAR CROSSS SECTION?"
360  PRINT : PRINT " 3. THE VELOCITY OF THE VEHICLES?"
370  PRINT : PRINT " 4. THE RANGE OF THE VEHICLES?"
380  PRINT : PRINT " 5. THE (S/N) AT THE OUTPUT OF THE RECEIVER?"
390  PRINT : PRINT " 6. THE RECEIVER NOISE FIGURE?"
400  PRINT : PRINT " 7. THE PLUMBING LOSSES?"
410  PRINT : PRINT " 8. THE AMIENT TEMPERATURE?"
420  PRINT : PRINT " 9. THE GAIN OF THE TRNSMIT & RECEIVE ANTENNA?"
430  INPUT C$
440  IF C$="1"  THEN PRINT : PRINT " ENTER THE OPERATING FREQ. fo IN GHz"
450  IF C$="1"  THEN INPUT fo : PRINT : PRINT " 1. fo=";fo;"GHz" : GOTO 620
460  IF C$="2"  THEN PRINT : PRINT " ENTER THE RADAR CROSS SECTION OF THE VEHICLES RCS
 INdbsm"
470  IF C$="2"  THEN INPUT RCS : PRINT : PRINT " 2. RCS=";RCS;"dbsm" : GOTO 620
480  IF C$="3"  THEN PRINT : PRINT " ENTER THE TRAVELING SPEED OF THE VEHICLES U IN
 mi/hrs"
490  IF C$="3"  THEN INPUT U : PRINT : PRINT " 3. U=";U;"mi/hrs" : GOTO 620
500  IF C$="4"  THEN PRINT : PRINT " ENTER THE RANGE THE RADAR WILL DETECT THE
 VEHICLES R IN MILES"
510  IF C$="4"  THEN INPUT R : PRINT : PRINT " 4. R=";R;"miles" : GOTO 620
520  IF C$="5"  THEN PRINT : PRINT " ENTER THE (S/N) REQUIRED AT THE OUTPUT OF THE IF
 AMPLIFIER SNout IN db"
530  IF C$="5"  THEN INPUT SNout : PRINT : PRINT " 5. (S/N)out=";SNout;"db" : GOTO 620
540  IF C$="6"  THEN PRINT : PRINT " ENTER THE RECEIVER NOISE FIGURE F IN db"
550  IF C$="6"  THEN INPUT F : PRINT : PRINT " 6. F=";F;"db" : GOTO 620
560  IF C$="7"  THEN PRINT : PRINT " ENTER THE PLUMBING LOSSES Lp IN db"
570  IF C$="7"  THEN INPUT Lp : PRINT : PRINT " 7. Lp=";Lp;"db" : GOTO 620
580  IF C$="8"  THEN PRINT : PRINT " ENTER THE NOISE TEMPERATURE OF THE RECEIVER Te IN
 KELVIN"
590  IF C$="8"  THEN INPUT Te : PRINT : PRINT " 8. Te=";Te;"Kelvin" : GOTO 620
600  IF C$="9"  THEN PRINT : PRINT " ENTER THE GAIN Gt OF THE TRANSMIT ANTENNA & Gr OF
 THE RECEIVE ANTENNA IN db"
610  IF C$="9"  THEN INPUT Gr,Gt : PRINT : PRINT " 9. Gt=",Gt, "Gr=";Gr;"db" : GOTO 620
620  PRINT : PRINT " IS EVERYTHING O.K NOW?"
```

```
630   INPUT B$
640   IF LEFT$(B$,1)="Y" OR LEFT$(B$,1)="y" THEN GOTO 690
650   PRINT : PRINT " WHAT DO YOU WANT TO CHANGE AGAIN?"
670   PRINT : PRINT " HIT ANY KEY IN YOUR KEYBOARD AND EVERYTHING WILL WORK FOR YOU
 MALAKA"
680   INPUT F$   : GOTO 340
690   RETURN
700 '**********************************
710   '       PRINTS THE INPUT DATA
720 '**********************************
730   LPRINT : LPRINT TAB(30); " PROBLEM #13"
740   LPRINT TAB(30); " -----------"
750   LPRINT : LPRINT " G I V E N"
760   LPRINT " ---------"
770   PRINT : PRINT " G I V E N"
780   PRINT " ---------"
790   PRINT : PRINT " 1. fo=";fo;"GHz" SPC(10); " : OPERATING FREQ."
800   LPRINT : LPRINT " 1. fo=";fo;"GHz" SPC(10); " : OPERATING FREQ."
810   PRINT : PRINT " 2. RCS=";RCS;"dbsm" SPC(9);" : VEHICLES RADAR CROSS SECTION"
820   LPRINT : LPRINT " 2. RCS=";RCS;"dbsm" SPC(9); " : VEHICLES RADAR CROSS SECTION"
830   PRINT : PRINT " 3. U=";U;"mi/hrs" SPC(7); " : VEHICLES'S TRAVELING VELOCITY"
840   LPRINT : LPRINT " 3. U=";U;"mi/hrs" SPC(7); " : VEHICLES'S TRAVELING VELOCITY"
850   PRINT : PRINT " 4. R=";R;"miles" SPC(9); " : RADAR-VEHICLE RANGE"
860   LPRINT : LPRINT " 4. R=";R;"miles" SPC(9); " : RADAR-VEHICLE RANGE"
870   PRINT : PRINT " 5. (S/N)out=";SNout;"db" SPC(5); " : SIGNAL-TO-NOISE RATIO AT THE
 OUTPUT OF THE RECEIVER"
880   LPRINT : LPRINT " 5. (S/N)out=";SNout;"db" SPC(5); " : SIGNAL-TO-NOISE RATIO AT THE
 OUTPUT OF THE RECEIVER"
890   PRINT : PRINT " 6. F=";F;"db" SPC(10); " : RECEIVER NOISE FIGURE"
900   LPRINT : LPRINT " 6. F=";F;"db" SPC(10); " : RECEIVER NOISE FIGURE"
910   PRINT : PRINT " 7. Lp=";Lp;"db" SPC(12); " : PLUMBING LOSSES"
920   LPRINT : LPRINT " 7. Lp=";Lp;"db" SPC(12); " : PLUMBING LOSSES"
930   PRINT : PRINT " 8. Ta=";Ta;"Kelvin" SPC(6);" : AMBIENT TEMPERATURE"
940   LPRINT : LPRINT " 8. Ta=";Ta;"Kelvin" SPC(6); " : AMBIENT TEMPERATURE"
950   PRINT : PRINT " 9. Gt=";Gt; "  Gr=";Gr;" db" SPC(1); " : TRANSMIT & RECEIVE ANTENNAS
```

```
 GAIN"
960   LPRINT :LPRINT " 9. Gt=";Gt; "  Gr=";Gr;" db" SPC(1); " : TRANSMIT & RECEIVE ANTENNAS
 GAIN"
970   RETURN
980  '************************************
990   ' CALCULATION & PRINTOUT OF PART a:
1000'************************************
1010  PRINT : PRINT : PRINT " PART a:"
1020  PRINT " -------:
1030  LPRINT : LPRINT : LPRINT " PART a:"
1040  LPRINT " -------:
1050  LET fo=fo*10^9 : U=U*.447 : R=R*1610 : C=3*10^8
1060  LET fd=2*u*fo/C : B=CINT(2*fd)
1070  PRINT : PRINT " B=";B/1000;"KHz"; " : RECEIVER BANDWIDTH"
1080  LPRINT : LPRINT " B=";B/1000;"KHz"; " :RECEIVER BANDWIDTH"
1090  RETURN
1100'************************************
1110  ' CALCULATION & PRINTOUT OF PART b:
1120'************************************
1130  PRINT : PRINT : PRINT " PART b:"
1140  PRINT " -------:
1150  LPRINT : LPRINT : LPRINT " PART b:"
1160  LPRINT " -------:
1170  LET K=1.38*10^-23 : T0=290 : F=F/10 : F=10^F  : Te=(F-1)*T0
1180 LET SNout=SNout/10 : SNout=10^SNout
1190 LET Sinp=K*(Ta+Te)*B*SNout : Sinp=CINT(10*.4342945**LOG(Sinp)+(Lp/2)+30)
1200  PRINT : PRINT " Sinp=";Sinp;"dbm"; " : RECEIVER INPUT SIGNAL POWER"
1210  LPRINT : LPRINT " Sinp=";Sinp;"dbm"; " : RECEIVER INPUT SIGNAL POWER"
1220  RETURN
1230'************************************
1240  ' CALCULATION & PRINTOUT OF PART c:
1250'************************************
1260  PRINT : PRINT : PRINT " PART c:"
1270  PRINT " -------:
1280  LPRINT : LPRINT : LPRINT " PART c:"
```

```
1290 LPRINT " -------:
1300 LET l=C/fo : PI=3.14159 : Lbf=CSNG(10*.4342945**2*LOG(4*PI*R/l))
1310 PRINT : PRINT " Lbf=";Lbf;"db"; " : ONE WAY FREE SPACE LOSSES FOR TARGET VEHICLES AT
 ARANGER=";R/1610;"miles"
1320 LPRINT : LPRINT " Lbf=";Lbf;"db"; " : ONE WAY FREE SPACE LOSSES FOR TARGET VEHICLES
 AT ARANGE R=";R/1610;"miles"
1330 RETURN
1340'**************************************
1350 ' CALCULATION & PRINTOUT OF PART d:
1360'**************************************
1370 PRINT : PRINT : PRINT " PART d:"
1380 PRINT " -------:
1390 LPRINT : LPRINT : LPRINT " PART d:"
1400 LPRINT " -------:
1410 LET RCS=RCS/10 : RCS=10^-RCS : Gs=10*.4342945**LOG(4*PI*RCS/l^2)
1420 LET Pt=CSNG(Sinp-Gs+(2*Lbf-Gt-Gr)+(Lp/2))
1430 PRINT : PRINT " Pt=";Pt;"dbm"; " : TRANSMITTER OUTPUT POWER"
1440 LPRINT : LPRINT " Pt=";Pt;"dbm"; " : TRANSMITTER OUTPUT POWER"
1450 RETURN
```

PROBLEM # 13

GIVEN

1. fo= 10 GHz : OPERATING FREQ.
2. RCS= 0 dbsm : VEHICLES RADAR CROSS SECTION
3. U= 100 mi/hrs : VEHICLES'S TRAVELING VELOCITY
4. R= .5 miles : RADAR-VEHICLE RANGE
5. (S/N)out= 15 db : SIGNAL-TO-NOISE RATIO AT THE OUTPUT OF THE RECEIVER
6. F= 7.25 db : RECEIVER NOISE FIGURE
7. Lp= 2 db : PLUMBING LOSSES
8. Te= 300 Kelvin : AMBIENT TEMPERATURE
9. Gt= 20 Gr= 20 db : TRANSMIT & RECEIVE ANTENNAS GAIN

PART a:

B= 5.96 KHz : RECEIVER BANDWIDTH

PART b:

Sinp= -113 dbm : RECEIVER INPUT SIGNAL POWER

PART c:

Lbf= 110.558 db : ONE WAY FREE SPACE LOSSES FOR TARGET VEHICLES AT A RANGE R= .5 miles

PART d:

Pt= 27.6663 dbm : TRANSMITTER OUTPUT POWER

```
10    PRINT : PRINT TAB(30); " PROBLEM # 14"
20    PRINT TAB(30); " ------------"
30    LPRINT : LPRINT TAB(30); " PROBLEM # 14"
40    LPRINT TAB(30); " ------------"
50    PRINT : PRINT " ENTER THE OPERATING FREQ. fo IN GHz"
60    INPUT fo: PRINT : PRINT " 1. fo=";fo;"GHz"
70    PRINT : PRINT " ENTER THE # OF THE STAGGER PERIODS n"
80    INPUT n : PRINT : PRINT " 2. n=";n
90    PRINT : PRINT " ENTER THE STAGGER PERIODS n1,n2,n3,n4"
100   INPUT n1,n2,n3,n4 : PRINT : PRINT " 3. T1 : T2 : T3 : T4 =";n1":"n2":"n3":"n4
110   PRINT : PRINT " ENTER THE TIME AVERAGE Tavg IN sec."
120   INPUT Tavg : PRINT : PRINT " 4. Tavg=";Tavg;"sec."
130   PRINT : PRINT : PRINT " G I V E N"
140   PRINT " ---------"
150   LPRINT : LPRINT : LPRINT " G I V E N"
160   LPRINT " ---------"
170   LPRINT : LPRINT " 1. fo=";fo;"GHz" SPC(10); " : OPERATING FREQ."
180   LPRINT : LPRINT " 2. n=";n SPC(14); " : # OF STAGGER PERIODS"
190   LPRINT : LPRINT " 3. T1:T2:T3:T4=";n1":"n2":"n3":"n4;" : RATIO OF STAGGER PERIODS"
200   LPRINT :LPRINT " 4. Tavg=";Tavg;"sec."; " : TIME AVERAGE"
230   PRINT : PRINT " 1. fo=";fo;"GHz" SPC(10); " : OPERATING FREQ."
240   PRINT : PRINT " 2. n=";n SPC(10); " : # OF STAGGER PERIODS"
250   PRINT : PRINT " 3. T1:T2:T3:T4=";n1":"n2":"n2":"n3":"n4; " : RATIO OF STAGGER PERIODS"
260   PRINT : PRINT " 4. Tavg=";Tavg;"sec."; " : TIME AVERAGE"
270   PRINT : PRINT : PRINT " PART a:"
280   PRINT " -------"
290   LPRINT : LPRINT : LPRINT " PART a:"
300   LPRINT " -------"
310   LET SUM=n1+n2+n3+n4
320   LET T1=n*n1/SUM*Tavg : T2=n*n2/SUM*Tavg : T3=n*n3/SUM*Tavg :
330   LET T4=n*n4/SUM*Tavg
340   LET T1=CSNG(T1*10^6) : T2=CSNG(T2*10^6) : T3=CSNG(T3*10^6) : T4=CSNG(T4*10^6)
350   PRINT : PRINT " 1. T1=";T1;"microsec.","  2. T2=";T2;"microsec."
360   PRINT : PRINT " 3. T3=";T3;"microsec.","  4. T4=";T4;"microsec."
370   LPRINT : LPRINT " 1. T1=";T1;"microsec.","  2. T2=";T2;"microsec."
```

```
380  LPRINT : LPRINT " 3. T3=";T3;"microsec.","  4. T4=";T4;"microsec."
390   PRINT : PRINT : PRINT " PART b:"
400   PRINT " -------"
410   LPRINT : LPRINT : LPRINT " PART b:"
420   LPRINT " -------"
430   LET C=3*10^8 : fo=fo*10^9 : l=C/fo
440  LET U1b1=l*(1/Tavg)*(1/1.02)*(SUM/n)
450  PRINT : PRINT " U1b1=";CINT(U1b1);"Knots"; ' : FIRST BLIND SPEED"
460  LPRINT : LPRINT " U1b1=";CINT(U1b1);"Knots"; " : FIRST BLIND SPEED"
470  PRINT : PRINT " DO YOU WANT TO TRY AGAIN WORKER Y/N?"
480   INPUT A$
490  IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y"  THEN 50
500   END
```

PROBLEM # 14

GIVEN

1. fo= 1 GHz : OPERATING FREQ.
2. n= 4 : # OF STAGGER PERIODS
3. T1:T2:T3:T4= 25 : 30 : 30 : 27 : 31 : RATIO OF STAGGER PERIODS
4. Tavg= .001 sec. : TIME AVERAGE

PART a:

1. T1= 884.956 microsec. 2. T2= 1061.95 microsec.
3. T3= 955.752 microsec. 4. T4= 1097.35 microsec.

PART b:

U1b1= 8309 Knots

```
10    PRINT : PRINT TAB(30); " PROBLEM # 15"
20    PRINT TAB(30); " -----------"
30    LPRINT : LPRINT TAB(30); " PROBLEM # 15"
40    LPRINT TAB(30); " -----------"
50    DIM N(50),A(50),B(50),W(50)
60    PRINT : PRINT " ENTER THE OPERATING FREQ. fo IN GHz"
70    INPUT fo : PRINT : PRINT " 1. fo=";fo;"GHz"
80    PRINT : PRINT " ENTER THE P.R.F fp IN KHz"
90    INPUT fp : PRINT : PRINT " 2. fp=";fp;"KHz"
100   PRINT : PRINT " ENTER NUMBER OF PULSE CANCELLER n, (maximum you can enter for this
program is n=49)"
110   INPUT n : PRINT : PRINT " 3. n=";n
120   PRINT : PRINT " ENTER FREQ. f IN Hz, WHERE THE CLUTTER REJECTION WILL BE
CALCULATED"
130   INPUT f : PRINT : PRINT " 4. f=";f;"Hz"
140   PRINT : PRINT " ENTER THE RADIAL VELOCITY OF THE TARGET Ur IN Knots"
150   INPUT Ur : PRINT : PRINT " 5. Ur=";Ur;"Knots"
160   '*****************************
170   '     PRINTS THE INPUT DATA
180   '*****************************
190   LPRINT : LPRINT : LPRINT " G I V E N"
200   LPRINT " ---------"
210   LPRINT : LPRINT " 1. fo=";fo;"GHz" SPC(10); " : OPERATING FREQ."
220   LPRINT : LPRINT " 2. fp=";fp;"KHz" SPC(10); " : P.R.F"
230   LPRINT : LPRINT " 3. n=";n SPC(14); " : NUMBER OF PULSE CANCELLER"
240   LPRINT : LPRINT " 4. f=";f;"Hz" SPC(11); " : FREQ. WHERE THE CLUTTER REJECTION WILL BE
CALCULATED"
250   LPRINT : LPRINT " 5. Ur=";Ur;"Knots" SPC(6); " : RADIAL VELOCITY OF THE TARGET"
260   '*****************************************
270   '     CALCULATIONS FOR PARTS a,b,c,d
280   '*****************************************
290   LET fo=fo*10^9 : fp=fp*10^3 : C=3*10^8
300   LET l=C/fo : U1b1=CSNG(l*fp/1.02)
310   PRINT : PRINT : PRINT " PART a:"
320   PRINT " -------"
```

```
330   LPRINT : LPRINT : LPRINT " PART a:"
340   LPRINT " -------"
350   PRINT : PRINT " U1b1=";U1b1;"Knots"; " : FIRST BLIND SPEED"
360   LPRINT : LPRINT " U1b1=";U1b1;"Knots"; " : FIRST BLIND SPEED"
370   PRINT : PRINT : PRINT " PART b:"
380   PRINT " -------"
390   LPRINT : LPRINT : LPRINT " PART b:"
400   LPRINT " -------"
410   FOR I=1 TO n-1
420      N(0)=1 : N(I)=I
430      N(I)=N(I-1)*I
440   NEXT I
450   FOR J=1 TO n
460       B(J)=J-1
470       B(1)=1
480       B(0)=1
490       A(0)=1
500       A(J)=B(J)*A(J-1) : PRINT A(J)
510    W(J)=(-1)^(J-1)*N(n-1)/(N(n-J)*A(J))
520   NEXT J
530   PRINT : PRINT " 1. T1 = T2 = T3 =";1/fp;"sec."; " : DELAYS OF THE 4 PULSE CANCELER"
540   LPRINT : LPRINT " 1. T1 = T2 = T3 =";1/fp;"sec."; " : DELAYS OF THE 4 PULSE CANCELER"
550   PRINT : PRINT " 2. THE WEIGHTS OF THE 4 PULSE CANCELER ARE : " : PRINT
560   LPRINT : LPRINT " 2. THE WEIGHTS OF THE 4 PULSE CANCELER ARE : " : LPRINT
570   FOR I=1 TO n
580     PRINT " W(";I;")";"=";W(I)"."; : LPRINT " W(";I;")";"=";W(I)".";
590   NEXT I
600   PRINT : PRINT : PRINT " PART c:"
610   PRINT " -------"
620   LPRINT : LPRINT : LPRINT " PART c:"
630   LPRINT " -------"
640   LET PI=3.14159 : REJ.=CSNG(-60*.4342945**LOG(SIN(PI*f/fp)))
650   PRINT : PRINT " REJ.=";REJ.;"db"; " : CLUTTER REJECTION AT f=";f;"Hz"
660   LPRINT : LPRINT " REJ.=";REJ.;"db"; " : CLUTTER REJECTION AT f=";f;"Hz"
670   PRINT : PRINT : PRINT " PART d:"
```

```
680    PRINT " -------"
690    LPRINT : LPRINT : LPRINT " PART d:"
700    LPRINT " -------"
710    LET fd=CSNG(1.03*Ur/1)
720    PRINT : PRINT " fd=";fd;"Hz"; " : DOPPLER FREQ. WHERE THE BIPOLAR VIDEO WILL
 FLUCTUATE"
730    LPRINT : LPRINT " fd=";fd;"Hz"; " : DOPPLER FREQ. WHERE THE BIPOLAR VIDEO WILL
 FLUCTUATE"
740    PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
750    INPUT A$
760    IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y" THEN 60
770    END
```

## PROBLEM # 15

GIVEN

1. fo= 1 GHz : OPERATING FREQ.
2. fp= 1 KHz : P.R.F
3. n= 4 : NUMBER OF PULSE CANCELLER
4. f= 25 Hz : FREQ. WHERE THE CLUTTER REJECTION WILL BE CALCULATED
5. Ur= 200 Knots : RADIAL VELOCITY OF THE TARGET

PART a:

U1bl= 294.118 Knots : FIRST BLIND SPEED

PART b:

1. T1 = T2 = T3 = .001 sec. : DELAYS OF THE 4 PULSE CANCELER
2. THE WEIGHTS OF THE 4 PULSE CANCELER ARE :

W( 1 )= 1 . W( 2 )=-3 . W( 3 )= 3 . W( 4 )=-1 .

PART c:

REJ.= 66.3214 db : CLUTTER REJECTION AT f= 25 Hz

PART d:

fd= 686.667 Hz : DOPPLER FREQ. WHERE THE BIPOLAR VIDEO WILL FLUCTUATE

# APPENDIX B

A listing of the Electronic Warfare computer programs is provided as well as an output of the results for each one of these programs.

```
10    PRINT : PRINT TAB(30); " PROBLEM #1 "
11    PRINT TAB(30); " ----------"
20    GOSUB 100 : GOSUB 850  : GOSUB 1060 : GOSUB 1510
30    GOSUB 1620   : GOSUB 1750   : GOSUB 1890 : GOSUB 2070 : GOSUB 2260
40    PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
50     INPUT D$
60    IF LEFT$(D$,1)="Y" OR LEFT$(D$,1)="y" THEN 20
70     END
80  '**********************************
90    '          INPUTS THE DATA
100 '**********************************
110   PRINT : PRINT " ENTER THE OPERATING FREQ. f0 IN MHZ"
120   INPUT f0 : PRINT : PRINT " 1. f0=";f0;"MHZ"
130   PRINT : PRINT " ENTER THE PULSE WIDTH (long) T1 IN MICSEC."
140   INPUT T1 : PRINT : PRINT " 2. T1=";T1;"MICSEC"
150   PRINT : PRINT " ENTER THE PULSE WIDTH (short) Ts IN MICSEC."
160   INPUT Ts : PRINT : PRINT " 3. Ts=";Ts;"MICSEC."
170   PRINT : PRINT " ENTER THE PEAK OUTPUT POWER Pr IN KW"
180   INPUT Pr : PRINT : PRINT " 4. Pr=";Pr;"KW"
190   PRINT : PRINT " ENTER THE P.R.F fp IN HZ"
200   INPUT fp : PRINT : PRINT " 5. fp=";fp;"HZ"
210   PRINT : PRINT " ENTER THE BANDWIDTH (long pulse) Brl IN MHZ"
220   INPUT Brl : PRINT : PRINT " 6. Brl=";Brl;"MHZ"
230   PRINT :PRINT " ENTER THE BANDWIDTH (short pulse) Brs IN MHZ"
240   INPUT Brs : PRINT : PRINT " 7. Brs=";Brs;"MHZ"
250   PRINT : PRINT " ENTER THE ANTENNA SCAN FREQ. Wm IN R.P.M"
260   INPUT Wm : PRINT : PRINT " 8. Wm=";Wm;"R.P.M"
270   PRINT : PRINT " ENTER THE AZIMUTH BEAMWIDTH A.B IN Deg."
280   INPUT A.B : PRINT : PRINT " 9. A.B=";A.B;"Deg."
290   PRINT : PRINT " ENTER THE ELEVATION BEAMWIDTH E.B IN Deg."
300   INPUT E.B : PRINT : PRINT " 10. E.B=";E.B;"Deg."
310   PRINT : PRINT " ENTER THE ANTENNA NOISE TEMPERATURE Ta IN KELVIN"
320   INPUT Ta : PRINT : PRINT " 11. Ta=";Ta;"KELVIN"
330   PRINT : PRINT " ENTER THE FALSE ALARM PROBABILITY Pfa"
340   INPUT Pfa: PRINT : PRINT " 12. Pfa=";Pfa
```

```
350  PRINT : PRINT " IS THE INPUT DATA CORRECT Y/N?"
360  INPUT A$
370  IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y" THEN 820
380  PRINT : PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
390  PRINT : PRINT " 1. THE OPERATING FREQ.?"
400  PRINT : PRINT " 2. THE PULSE WIDTH (long) ?"
410  PRINT : PRINT " 3. THE PULSE WIDTH (short) ?"
420  PRINT : PRINT " 4. THE PEAK OUTPUT POWER"
430  PRINT : PRINT " 5. THE P.R.F"
440  PRINT : PRINT " 6. THE BANDWIDTH FOR THE LONG PULSE?"
450  PRINT : PRINT " 7. THE BANDWIDTH FOR THE SHORT PULSE?"
460  PRINT : PRINT " 8. THE ANTENNA SCAN FREQ.?"
470  PRINT : PRINT " 9. THE AZIMUTH BEAMWIDTH?"
480  PRINT : PRINT " 10. THE ELEVATION BEAMWIDTH?"
490  PRINT : PRINT " 11. THE ANTENNA NOISE TEMPERATURE?"
500  PRINT : PRINT " 12. THE FALSE ALARM PROBABILITY?"
510  INPUT C$
520  IF C$="1" THEN PRINT : PRINT " ENTER THE OPERATING FREQ. f0 IN MHZ"
530  IF C$="1" THEN INPUT f0 : PRINT : PRINT " 1. f0=";f0;"MHZ" : GOTO 760
540  IF C$="2" THEN PRINT : PRINT " ENTER THE PULSE WIDTH (long) T1 IN MICSEC."
550  IF C$="2" THEN INPUT T1 : PRINT : PRINT " 2. T1=";T1;"MICSEC." : GOTO 760
560  IF C$="3" THEN PRINT : PRINT " ENTER THE PULSE WIDTH (short) Ts IN MICSEC."
570  IF C$="3" THEN INPUT Ts : PRINT : PRINT " 3. Ts=";Ts;"MICSEC." : GOTO 760
580  IF C$="4" THEN PRINT : PRINT " ENTER THE PEAK POWER OUTPUT Pr IN KW"
590  IF C$="4" THEN INPUT Pr : PRINT : PRINT " 4. Pr=";Pr;"KW" : GOTO 760
600  IF C$="5" THEN PRINT : PRINT " ENTER THE P.R.F pf IN HZ"
610  IF C$="5" THEN INPUT pf : PRINT : PRINT " 5. pf=";pf;"HZ" : GOTO 760
620  IF C$="6" THEN PRINT : PRINT " ENTER THE BANDWIDTH (long pulse) Brl IN MHZ"
630  IF C$="6" THEN INPUT Brl : PRINT : PRINT " 6. Brl=";Brl;"MHZ" : GOTO 760
640  IF C$="7" THEN PRINT : PRINT " ENTER THE BANDWIDTH (short pulse) Brs IN MHZ"
650  IF C$="7" THEN INPUT Brs : PRINT : PRINT " 7. Brs=";Brs;"MHZ" : GOTO 760
660  IF C$="8" THEN PRINT : PRINT " ENTER THE ANTENNA SCAN FREQ. Wm IN R.P.M"
670  IF C$="8" THEN INPUT Wm : PRINT : PRINT " 8. Wm=";Wm;"R.P.M" : GOTO 760
680  IF C$="9" THEN PRINT : PRINT " ENTER THE AZIMUTH BEAMWIDTH A.B IN Deg."
690  IF C$="9" THEN INPUT A.B : PRINT : PRINT " 9. A.B=";A.B;"Deg." : GOTO 760
```

```
700   IF C$="10" THEN PRINT : PRINT " ENTER THE ELEVATION BEAMWIDTH E.B IN Deg."
710   IF C$="10"  THEN INPUT E.B : PRINT : PRINT " 10. E.B=";E.B;"Deg." : GOTO 760
720   IF C$="11" THEN PRINT : PRINT " ENTER THE ANTENNA NOISE TEMPERATURE Ta IN KELVIN"
730   IF C$="11"  THEN INPUT Ta : PRINT : PRINT " 11. Ta=";Ta;"KELVIN" : GOTO 760
740   IF C$="12" THEN PRINT : PRINT " ENTER THE FALSE ALARM PROBABILITY Pfa"
750   IF C$="12"  THEN INPUT Pfa : PRINT : PRINT " 12. Pfa= ";Pfa; : GOTO 760
760   PRINT : PRINT " IS EVERYTHING O.K NOW?"
770   INPUT B$
780   IF LEFT$(B$,1)="Y" OR LEFT$(B$,1)="y" THEN 820
790   PRINT : PRINT " WHAT DO YOU WANT TO CHANGE AGAIN?"
800   PRINT : PRINT " HIT ANY KEY IN YOUR KEYBOARD AND EVERYTHING WILL WORK FOR YOU
   MALAKA"
810   INPUT F$   : GOTO 390
820   RETURN
830 '*********************************
840   '      PRINTS THE INPUT DATA
850 '*********************************
860   LPRINT : LPRINT TAB(30); " PROBLEM # 1"
870   LPRINT TAB(30); " ----------"
880   LPRINT : LPRINT " G I V E N"
890   LPRINT " ---------"
900   PRINT : PRINT " G I V E N"
920   LPRINT : LPRINT " 1. f0=";f0;"MHZ" TAB(20);" : OPERATING FREQ."
930   LPRINT : LPRINT " 2. T1=";T1;"MICSEC." TAB(20);" : PULSE WIDTH (long)"
940   LPRINT : LPRINT " 3. Ts=";Ts;"MICSEC." TAB(20);" : PULSE WIDTH (short)"
950   LPRINT : LPRINT " 4. Pr=";Pr;"KW" TAB(20);" : PEAK OUTPUT POWER"
960   LPRINT : LPRINT " 5. fp=";fp;"HZ" TAB(20);" : P.R.F"
970   LPRINT : LPRINT " 6. Brl=";Brl;"MHZ"TAB(20);" : BANDWIDTH  (long pulse)"
980   LPRINT : LPRINT " 7. Brs=";Brs;"MHZ" TAB(20);" : BANDWIDTH (short pulse)"
990   LPRINT : LPRINT " 8. Wm=";Wm;"R.P.M" TAB(20);" : ANTENNA SCAN FREQ."
1000  LPRINT : LPRINT " 9. A.B=";A.B;"Deg." TAB(20);" : AZIMUTH BEAMWIDTH"
1010  LPRINT : LPRINT "  10. E.B=";E.B;"Deg." TAB(20);"  : ELEVATION BEAMWIDTH"
1020  LPRINT : LPRINT " 11. Ta=";Ta;"KELVIN" TAB(20);" : ANTENNA NOISE TEMPERATURE"
1030  LPRINT : LPRINT " 12. Pfa=";Pfa; TAB(20);" : FALSE ALARM PROBABILITY"
1040  RETURN
```

```
1050*************************************************
1060 '       CALCULATION & PRINTOUT FOR PART e
1070*************************************************
1080 PRINT : PRINT : PRINT " PART e:"
1090 PRINT " -------"
1100 LPRINT : LPRINT : LPRINT " PART e:"
1110 LPRINT " -------"
1120 PRINT : PRINT " ENTER RADAR'S CROSS SECTION OF TARGET Sav IN sq.m"
1130 INPUT S
1140 PRINT : PRINT " ENTER THE PROBABILITY OF DETECTION Pd"
1150 INPUT Pd
1160 PRINT : PRINT " ENTER THE RECEIVER'S NOISE FIGURE F1 IN db"
1170 INPUT F1
1180 LET n=CINT(A.B*fp*60/(360*Wm))
1190 PRINT : PRINT " FROM Fig. 2.8(a) (SKOLNIK Pg.31) YOU CAN FIND THE INTEGRATION IMR.
          FACTOR I1(n) IN db"
1200 PRINT : PRINT " SINCE YOU KNOW :"
1210 PRINT : PRINT " (a). n=A.B*fp*60/(360*Wm)=";n; " : #OF HITS INTEGRATED"
1220 PRINT : PRINT " (b). Pd=";Pd; " : PROBABILITY OF DETECTION"
1230 PRINT : PRINT " ENTER THE INTEGRATION IMR. FACTOR I1(n) (numeric value)"
1240 INPUT I1
1250 PRINT : PRINT " FROM Fig. 2.7 (SKOLNIK Pg. 28) YOU CAN FIND THE (S/N)1 IN db"
1260 PRINT : PRINT " ENTER THE (S/N)1 IN db"
1270 INPUT A
1280 LET T0=290              'KELVIN
1290 LET K=1.38*10^-23       'BOLTZMAN'S CONSTANT
1300 LET PI=3.14159
1310 LET C=3*10^8            'm/s
1320 LET f0=f0*10^6          'convertion from MHz to Hz
1330 LET Br1=Br1*10^6        'convertion from MHz to Hz
1340 LET Pr=Pr*10^3          'convertion from MW to W
1350 LET l=C/f0              'm/s
1360 LET G=41250!/(A.B*E.B)        'ANTENNA GAIN
1370 LET Ae=l^2*G/(4*PI)     'antenna effective aperture
1380 LET F2=F1/10 : F3=10^F2
```

```
1390 LET Te=(F3-1)*T0
1400 LET B=K*T0*(Ta+Te)*Br1/290
1410 LET A1=A/10 : A2=10^A1
1420 LET R=CSNG(SQR(SQR(Pr*G*Ae*S*11/((4*PI)^2*B*A2)))) 'long pulse
1430 LET R1=CSNG(R*(1/5)^(1/4))        'short pulse
1450 PRINT : PRINT " 1(a).
        R=Pr*G*Ae*Sav*n*E1(n)/((4*PI)^2*K*(Ta+Te)*Br1*(S/N)max.)^(1/4)=";R/1000;"KM";"
        MAX.DETECTION RANGE FOR THE LONG PULSE"
1460 PRINT : PRINT " 2(a). R1=R*(1/5)^(1/4)=";R1/1000;"KM"; " : MAX RANGE FOR THE SHORT
        PULSE"
1470 LPRINT : LPRINT " 1(a).
        R=Pr*G*Ae*Sav*n*E1(n)/((4*PI)^2*K(Ta+Te)*Br1*(S/N)max.)^(1/4)=";R/1000;"KM";"
        MAX.DETECTION RANGE FOR THE LONG PULSE"
1480 LPRINT : LPRINT " 2(a). R1=R*(1/5)^(1/4)=";R1/1000;"KM"; " : MAX RANGE FOR THE SHORT
        PULSE"
1490 RETURN
1500'*************************************
1510 '  CALCULATION& PRINTOUT FOR PART b:
1520'*************************************
1530 PRINT : PRINT : PRINT " PART b:"
1540 PRINT " -------"
1550 LPRINT : LPRINT : LPRINT " PART b:"
1560 LPRINT " -------"
1570 LET Ru=CSNG(C/(2*fp))
1580 PRINT : PRINT " 1(b). Ru=";Ru/1000;"KM" " : MAX. UNAMBIGUOUS RANGE"
1590 LPRINT : LPRINT " 1(b). Ru=";Ru/1000;"KM" " : MAX. UNAMBIGUOUS RANGE"
1600 RETURN
1610'*************************************
1620 '  CALCULATION& PRINTOUT FOR PART c:
1630'*************************************
1640 PRINT : PRINT : PRINT " PART c:"
1650 PRINT " -------"
1660 LPRINT : LPRINT : LPRINT " PART c:"
1670 LPRINT " -------"
1680 PRINT : PRINT "ENTER THE RADAR CROSS SECTION IN dbsm"
```

```
1690  INPUT Slev
1700 LET R2=CSNG(R/1000*10^(1/4))
1710  PRINT : PRINT " I(c). R2= 10^(1/4)*R=";R2;"KM"; " RANGE AT WHICH THE AIRCRAFT WILL BE
          DETECTED FOR R.C.S= 10sq.m & FOR THE LONG PULSE"
1720  LPRINT : LPRINT " I(c). R2= 10^(1/4)*R=";R2;"KM"; " RANGE AT WHICH THE AIRCRAFT WILL BE
          DETECTED FOR R.C.S= 10sq.m & FOR THE LONG PULSE"
1730  RETURN
1740'*************************************
1750  '  CALCULATION & PRINTOUT FOR PART d:
1760'*************************************
1770  PRINT : PRINT : PRINT " PART d:"
1780  PRINT " -------"
1790  LPRINT : LPRINT : LPRINT " PART d:"
1800  LPRINT " -------"
1810  PRINT : PRINT " ENTER THE RADAR ANTENNA HEIGHT ABOVE THE SEA h1 IN ft"
1820  INPUT h1
1830 LET h2=(R2/1.61-SQR(2*h1))^2
1840  LET h2=CSNG(h2/2)
1850  PRINT : PRINT " I(d). h2=R2(mi)-SQR(2*h1(ft)))/2=";h2;" ft"; " : MIN. ALTITUDE AT WHICH
          THE RADAR CAN SEE THE TARGET"
1860  LPRINT : LPRINT " I(d). (h2=R2(mi)-SQR(2*h1(ft)))/2=";h2;" ft"; " : MIN. ALTITUDE AT WHICH
          THE RADAR CAN SEE THE TARGET"
1870 RETURN
1880'*************************************
1890  '  CALCULATION & PRINTOUT FOR PART e:
1900'*************************************
1910  PRINT : PRINT : PRINT " PART e:"
1920  PRINT " -------"
1930  LPRINT : LPRINT : LPRINT " PART e:"
1940  LPRINT " -------"
1950  PRINT : PRINT " ENTER THE CIRCULARY POLARIZED ANTENNA'S GAIN GO IN db"
1960  INPUT GO
1970  LET G1=GO/10 : G2=10^G1
1980  PRINT : PRINT " ENTER THE TOTAL SYSTEM LOSSES Ls IN db"
1990  INPUT Ls
```

```
2000 LET Ls1=Ls/10:Ls2=10^Ls1
2010P=Pr*G*1^2*G2/((4*PI)^2*(R2*1000)^2*Ls2)
2020 LETP=CSNG(10*.4342945**LOG(P)+30)
2030 PRINT:PRINT " 1(e).P=Pr*G*1^2*G2/((4*PI)^2*R2^2*Ls)=";P;"dbm";":SINGLE PULSE POWER
     AT THE ANTENNA TERMINALS OUTPUT"
2040 LPRINT:LPRINT " 1(e).P=Pr*G*1^2*G2/((4*PI)^2*R2^2*Ls)=";P;"dbm";":SINGLE PULSE
     POWER AT THE ANTENNA TERMINALS OUTPUT"
2050 RETURN
2060'*************************************
2070 ' CALCULATION& PRINTOUT FOR PART f:
2080'*************************************
2090 PRINT:PRINT:PRINT " PART f:"
2100 PRINT " -------"
2110 LPRINT:LPRINT:LPRINT " PART f:"
2120 LPRINT " -------"
2130 LET K1=1640
2140 LET K2=400
2150 LET T1=T1*10^-6
2160 LET Cf=4/(1+(1/(T1*Br1))^2)*(fp/K1)^(1/3)
2170 LET Cf1=4/(1+(1/(T1*Br1))^2)*(fp/K2)^(1/3)
2180 LET Cf=CSNG(10*.4342945**LOG(Cf))
2190 LET Cf1=CSNG(10*.4342945**LOG(Cf1))
2200 PRINT:PRINT " 1(f).Cf=4/(1+(1/(T1*Br1))^2)*(fp*K)^(1/3)=";Cf;"db";":CAMOUFLAGE
     FACTOR FOR K=";K1
2210 PRINT:PRINT " 2(f).Cf1=4/(1+(1/(T1*Br1))^2)*(fp*K)^(1/3)=";Cf1;"db";":CAMOUFLAGE
     FACTOR FOR K=";K2
2220 LPRINT:LPRINT " 1(f).Cf=4/(1+(1/(T1*Br1))^2)*(fp*K)^(1/3)=";Cf;"db";":CAMOUFLAGE
     FACTOR FOR K=";K1
2230 LPRINT:LPRINT " 2(f).Cf1=4/(1+(1/(T1*Br1))^2)*(fp*K)^(1/3)=";Cf1;"db";":CAMOUFLAGE
     FACTOR FOR K=";K2
2240 RETURN
2250'*************************************
2260 ' CALCULATION& PRINTOUT FOR PART g:
2270'*************************************
2280 PRINT:PRINT:PRINT " PART g:"
```

```
2290  PRINT " -------"
2300  LPRINT : LPRINT : LPRINT " PART g:"
2310  LPRINT " -------"
2320  PRINT : PRINT " ENTER THE VALUE OF THE S/J IN db"
2330  INPUT C1 : C2=C1/10 : C3=10^C2
2340  PRINT : PRINT " ENTER THE BURNTHROUGH RANGE Rb IN n.miles"
2350  INPUT Rb
2360  LET Rb=Rb*1.85*10^3
2370  PRINT : PRINT " ENTER THE THE FREQ. Br IN MHz THE JAMMER TRANSMITS"
2380  INPUT Br : Br=Br*10^6
2390  PRINT : PRINT " ENTER THE GAIN OF THE JAMMING ANTENNA Gj IN db"
2400  INPUT Gj : Cj1=Cj/10 . Cj2=10^Cj1
2410Pj=CSNG(Pr*G*Slav*Ls2*C3/(4*PI*Rb^2*Br1*Cj2))
2420Pj1=CSNG(Pr*G*Slav*Ls2*C3/(4*PI*Rb^2*Br*Cj2))
2430 PRINT : PRINT " 1(g). Pj=Pr*G*Sav*Ls*(S/J)/(4*PI*Rb^2*Br1*Cj)=";Pj*10^6;"W/MHz"; " :
        JAMMER OUTPUT POWER FOR LONG PULSE"
2440 PRINT : PRINT " 2(g). Pj=Pr*G*Sav*Ls*(S/J)/(4*PI*Rb^2*Br*Cj)=";Pj1*10^6;"W/MHz"; " :
        JAMMER OUTPUT POWER FOR Br="Br/10^6;"MHz
2450 LPRINT : LPRINT " 1(g). Pj=Pr*G*Sav*Ls*(S/J)/(4*PI*Rb^2*Br1*Cj)=";Pj*10^6;"W/MHz"; " :
        JAMMER OUTPUT POWER FOR LONG PULSE"
2460 LPRINT : LPRINT " 2(g). Pj=Pr*G*Sav*Ls*(S/J)/(4*PI*Rb^2*Br*Cj)=";Pj1*10^6;"W/MHz"; " :
        JAMMER OUTPUT POWER FOR Br="Br/10^6;"MHz
2470  RETURN
```

PROBLEM*1

GIVEN

1. f0= 5600 MHZ : OPERATING FREQ.
2. T1= 1.3 MICSEC. : PULSE WIDTH (long)
3. Ts= .25 MICSEC. : PULSE WIDTH (short)
4. Pr= 200 KW : PEAK OUTPUT POWER
5. fp= 650 HZ : P.R.F
6. Br1= 1 MHZ : BANDWIDTH (long pulse)
7. Brs= 5 MHZ : BANDWIDTH (short pulse)
8. Wm= 16 R.P.M : ANTENNA SCAN FREQ.
9. A.B= 1.5 Deg. : AZIMUTH BEAMWIDTH
10. E.B= 14 Deg. : ELEVATION BEAMWIDTH
11. Ta= 75 KELVIN : ANTENNA NOISE TEMPERATURE
12. Pfa= 1E-11 : FALSE ALARM PROBABILITY

PART a:

1(a).R=Pr*G*Ae*Sav*n*E1(n)/((4*PI)^2*K*(Ta+Te)*Br1*(S/N)max.)^(1/4)= 47.972KM.MAX DETECTION RANGE FOR THE LONG PULSE

2(a). R1=R*(1/5)^(1/4)= 32.0808 KM : MAX RANGE FOR THE SHORT PULSE

PART b:

1(b). Ru= 230.769 KM : MAX. UNAMBIGUOUS RANGE

PART c:

1(c). R2=10^(1/4)*R= 85.3076 KM RANGE AT WHICH THE AIRCRAFT WILL BE DETECTED FOR R.C.S=10sq.m& FOR THE LONG PULSE

PART d:

1(d). h2=R2(mi)-SQR(2*h1(ft)))/2= 923.902 ft : MIN. ALTITUDE AT WHICH THE RADAR CAN SEE THE TARGET

PART e:

1(e).P=Pr*G*1^2*G2/((4*PI)^2*R2^2*Ls)=-33.0829 dbm : SINGLE PULSE POWER AT THE ANTENNA TERMINALS OUTPUT

PART f:

1(f). Cf=4/(1+(1/(T1*Br1))^2)*(fp*K)^(1/3)=2.66218 db : CAMOUFLAGE FACTOR FOR K= 1640

2(f). Cf1=4/(1+(1/(T1*Br1))^2)*(fp*K)^(1/3)=4.70479 db : CAMOUFLAGE FACTOR FOR K= 400

PART g:

1(g). Pj=Pr*G*Sav*Ls*(S/J)/(4*PI*Rb^2*Br1*Cj)=5.76344 W/MHz : JAMMER OUTPUT POWER FOR LONG PULSE

2(g). Pj=Pr*G*Sav*Ls*(S/J)/(4*PI*Rb^2*Br*Cj)=.192115 W/MHz : JAMMER OUTPUT POWER FOR Br= 30 MHz

```
10    PRINT : PRINT TAB(30) " PROBLEM #2 "
20    PRINT TAB(30); " ----------"
30    GOSUB 100 : GOSUB 530  : GOSUB 690
40    GOSUB 840 : GOSUB 950 : GOSUB 1060
50    PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
60     INPUT D$
70    IF LEFT$(D$,1)="Y" OR LEFT$(D$,1)="y" THEN 30
80     END
90   '*********************************
100   '          INPUTS THE DATA
110  '*********************************
120   PRINT : PRINT " ENTER THE OPERATING FREQ. f0 IN MHz "
130   INPUT f0 : PRINT : PRINT " 1. f0=";f0;"MHz "
140   PRINT : PRINT " ENTER THE DIMENSIONS OF THE RECTANGULAR TRANSMIT ANTENNA d1,d2
 IN METERS"
150   INPUT d1,d2 : PRINT : PRINT " 2. d1xd2="d1 "x" d2 " m"
160   PRINT : PRINT " ENTER THE #OF ELEMENTS OF THE RECT. ARRAY,TRANSMIT ANTENNA N "
170   INPUT N1 : PRINT : PRINT " 3. N=";N1
180   PRINT : PRINT " ENTER THE ILLUMINATION EFFICIENCY OF THE ARRAY Rr"
190   INPUT Rr : PRINT : PRINT " 4. Rr=";Rr
200   PRINT : PRINT " ENTER THE TOTAL LOSSES Ls (feed & phase shifter) IN db"
210   INPUT Ls : PRINT : PRINT " 5. Ls=";Ls;"db"
220   PRINT : PRINT " IS THE INPUT DATA CORRECT Y/N?"
230   INPUT A$
240   IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y"  THEN 500
250   IF A$="y"   THEN 1041
260   IF A$="N"   THEN PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
270   IF A$="n"   THEN PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
280   PRINT : PRINT "  1. THE OPERATING FREQ.?"
290   PRINT : PRINT " 2. THE DIMENSIONS OF THE RECT.ARRAY?"
300   PRINT : PRINT " 3. #OF THE ELEMENTS?"
310   PRINT : PRINT " 4. ILLUMINATION EFFICIENCY?"
320   PRINT : PRINT " 5. THE TOTAL LOSSES?"
330   INPUT C$
340   IF C$="1"   THEN PRINT : PRINT " ENTER THE OPERATING FREQ. f0 IN MHz"
```

```
350   IF C$="1"   THEN INPUT f0 : PRINT : PRINT " 1. f0=";f0;"MHz" : GOTO 440
360   IF C$="2"   THEN PRINT : PRINT " ENTER THE DIMENSIONS OF THE RECT. TRANSMIT
 ANTENNA d1,d2 IN METERS"
370   IF C$="2"   THEN INPUT d1,d2 : PRINT : PRINT " 2. d1xd2="d1 "x" d2 " m"  : GOTO 440
380   IF C$="3"   THEN PRINT : PRINT " ENTER THE #OF ELEMENTS OF THE RECT.
 ARRAY,TRANSMIT ANTENNA N "
390   IF C$="3"   THEN INPUT N1 : PRINT : PRINT " 3. N=";N1  : GOTO 440
400   IF C$="4"   THEN PRINT : PRINT " ENTER THE ILLUMINATION EFFICIENCY OF THE ARRAY Rr"
410   IF C$="4"   THEN INPUT Rr : PRINT : PRINT " 4. Rr=";Rr  : GOTO 440
420   IF C$="5"   THEN PRINT : PRINT " ENTER THE TOTAL LOSSES Ls (feed & phase shifter) IN
 db"
430   IF C$="5"   THEN INPUT Ls : PRINT : PRINT " 5. Ls=";Ls;"db" : GOTO 440
440   PRINT : PRINT " IS EVERYTHING O.K NOW?"
450   INPUT B$
460   IF LEFT$(B$,1)="Y"  OR LEFT$(B$,1)="y"  THEN 500
470   PRINT : PRINT " WHAT DO YOU WANT TO CHANGE AGAIN?"
480   PRINT : PRINT " HIT ANY KEY IN YOUR KEYBOARD AND EVERYTHING WILL WORK FOR YOU
 MALAKA"
490   INPUT F$   : GOTO 280
500   RETURN
510 '*********************************
520   '       PRINTS THE INPUT DATA
530 '*********************************
540   LPRINT : LPRINT TAB(30); " PROBLEM #2"
550   LPRINT  TAB(30); " ----------"
560   LPRINT : LPRINT " G I V E N"
570   LPRINT " ---------"
580   LPRINT : LPRINT " 1. f0=";f0;"MHz" TAB(20) " : OPERATING FREQ."
590   LPRINT : LPRINT " 2. d1xd2="d1 "x" d2 " m" TAB(20); " : DIMENSIONS OF THE ARRAY
 ANTENNA"
600   LPRINT : LPRINT " 3. N=";N1 TAB(20); " : #OF ELEMENTS OF THE ARRAY ANTENNA"
610   LPRINT : LPRINT " 4. Rr=";Rr TAB(20); " : ILLUMINATION EFF. OF THE ARRAY"
620   LPRINT : LPRINT " 5. Ls=";Ls;"db" TAB(20); " : TOTAL LOSSES (feed & phase shifter)"
670   RETURN
680 '*****************************************
```

```
690   '   CALCULATION & PRINTOUT FOR PART a:
700 '*****************************************
710   PRINT : PRINT : PRINT " PART a:"
720   PRINT " -------"
730   LPRINT : LPRINT : LPRINT " PART a:"
740   LPRINT " -------"
750   LET Ls1=10^(-Ls/10) :  A=d1*d2
760   LET Ae= Rr*Ls1*A :  PI=3.14159
770   LET C=3*10^8 : f0=f0*10^6
780   LET l=C/f0 :  Gp=CSNG(4*PI*Ae/(l^2))
790  LET Gp1=CSNG(10*.4342945**LOG(Gp))
800   PRINT : PRINT " 1(a). Gp=4*PI*Ae/(l^2)=";Gp;" numeric";" or";Gp1;"db"; " : POWER GAIN"
810   LPRINT : LPRINT " 1(a). Gp=4*PI*Ae/(l^2)=";Gp;" numeric";" or";Gp1;"db"; " : POWER GAIN"
820   RETURN
830 '*****************************************
840   '   CALCULATION & PRINTOUT FOR PART b:
850 '*****************************************
860   PRINT : PRINT : PRINT " PART b:"
870   PRINT " -------"
880   LPRINT : LPRINT : LPRINT " PART b:"
890   LPRINT " -------"
900  LET TH=CSNG(SQR(41250!/(Gp/Ls1)))
910  PRINT : PRINT " 1(b). TH=SQR(41250!/(Gp/Ls1))=";TH;"Deg."; " : BEAMWIDTH"
920  LPRINT : LPRINT " 1(b). TH=SQR(41250!/(Gp/Ls1))=";TH;"Deg."; " : BEAMWIDTH"
930   RETURN
940 '*****************************************
950   '   CALCULATION & PRINTOUT FOR PART c:
960 '*****************************************
970   PRINT : PRINT : PRINT " PART c:"
980   PRINT " -------"
990   LPRINT : LPRINT : LPRINT " PART c:"
1000  LPRINT " -------"
1010 LET d=CSNG(d1/SQR(N1))
1020  PRINT : PRINT " 1(c). d=d1/SQR(N1)=";d; " : SPACING BETWEEN ELEMENTS"
1030  LPRINT : LPRINT " 1(c). d=d1/SQR(N1)=";d; " : SPACING BETWEEN ELEMENTS"
```

```
1040 RETURN
1050'*****************************************
1060 '  CALCULATION & PRINTOUT FOR PART d:
1070'*****************************************
1080 PRINT : PRINT : PRINT " PART d:"
1090 PRINT " -------"
1100 LPRINT : LPRINT : LPRINT " PART d:"
1110 LPRINT " -------"
1120 LET Gdel=CSNG(12795/N1)
1130 LET Gdel1=CSNG(10*.4342945**LOG(Gdel))
1140 PRINT:PRINT " 1(d). Gdel=Gdarray/Gdgroup=";Gdel;"numeric";" or";Gdel1;"db";":
 DIRECTIVE GAIN OF AN ELEMENT"
1150 LPRINT: LPRINT " 1(d). Gdel=Gdarray/Gdgroup=";Gdel;"numeric";" or";Gdel1;"db";"
 DIRECTIVE GAIN OF AN ELEMENT"
1160 RETURN
```

## PROBLEM#2

GIVEN

1. f0= 442 MHz : OPERATING FREQ.
2. d1xd2= 26.9 x 26.9 m : DIMENSIONS OF THE ARRAY ANTENNA
3. N= 5184 : #OF ELEMENTS OF THE ARRAY ANTENNA
4. Rr= .65 : ILLUMINATION EFF. OF THE ARRAY
5. Ls= 1.8 db : TOTAL LOSSES (feed & phase shifter)

PART a:

1(a). Gp=4*PI*Ae/(1^2)= 8476.75 numeric or 39.2823 db : POWER GAIN

PART b:

1(b).TH=SQR(41250!/(Gp/Ls1))= 1.79307 Deg. : BEAMWIDTH

PART c:

1(c). d=d1/SQR(N1)= .373611 : SPACING BETWEEN ELEMENTS

PART d:

1(d). Gdel=Gdarray/Gdgroup= 2.46817 numeric or 3.92375 db : DIRECTIVE GAIN OF AN ELEMENT

```
10   PRINT : PRINT TAB(30) " PROBLEM #3 "
20   PRINT TAB(30); " --------"
30   GOSUB 100  : GOSUB 1170
40   GOSUB 1430 : GOSUB 1590
50   PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
60   INPUT D$
70   IF LEFT$(D$,1)="Y" OR LEFT$(D$,1)="y"  THEN 30
80   END
90  '**********************************
100  '          INPUTS THE DATA
120 '**********************************
130  PRINT : PRINT " ENTER THE OUTPUT PEAK POWER Pt IN W"
140  INPUT Pt : PRINT : PRINT " 1. Pt=";Pt;"W"
150  PRINT : PRINT " ENTER THE BORESIGHT ANTENNA GAIN Gt IN db"
160  INPUT Gt : PRINT : PRINT " 2. Gt=";Gt;"db"
170  PRINT : PRINT " ENTER THE OPERATING FREQ. f0 In GHz"
180  INPUT f0 : PRINT : PRINT " 3. f0=";f0;"GHz"
190  PRINT : PRINT " ENTER THE RF LOSSES Lp IN db"
200  INPUT Lp : PRINT : PRINT " 4. Lp=";Lp;"db"
210  PRINT :PRINT " ENTER THE RECEIVER NOISE BANDWIDTH Bn IN MHz"
220  INPUT Bn : PRINT : PRINT " 5. Bn=";Bn;"MHz"
230  PRINT : PRINT " ENTER THE RECEIVER NOISE FIGURE F IN db"
240  INPUT F : PRINT : PRINT " 6. F=";f;"db"
250  PRINT : PRINT " ENTER THE PULSE WIDTH T IN ns"
260  INPUT T : PRINT : PRINT " 7. T=";T;"ns"
270  PRINT : PRINT " ENTER THE P.R.F fp IN KHz"
280  INPUT fp : PRINT : PRINT " 8. fp=";fp;"KHz"
290  PRINT : PRINT " ENTER THE INTEGRATION TIME Ti IN msec."
300  INPUT Ti : PRINT : PRINT " 9. Ti=";Ti;"msec."
310  PRINT : PRINT " ENTER THE WEATHER ATTENUATION At IN db/KM"
320  INPUT At : PRINT : PRINT " 10. At=";At;"db/KM"
330  PRINT : PRINT " ENTER THE SKY TEMPERATURE Ta IN KELVIN"
340  INPUT Ta : PRINT : PRINT " 11. Ta=";Ta;"KELVIN"
350  PRINT : PRINT " ENTER THE TARGET RCS IN dbsm"
360  INPUT RCS : PRINT : PRINT " 12. RCS=";RCS;"dbsm"
```

```
370  PRINT : PRINT " ENTER THE DEG. OF THE PENCIL BEAM PB (part b)"
380  INPUT PB : PRINT : PRINT " 13. PB=";PB;"Deg."
390  PRINT : PRINT " ENTER THE (J/S) JS IN db (part b)"
400  INPUT JS : PRINT : PRINT " 14. (J/S)=";JS;"db"
410  PRINT : PRINT " ENTER THE RANGE R IN KM (part c)"
420  INPUT R : PRINT : PRINT " 15. R=";R;"KM"
430  PRINT : PRINT " ENTER THE RF LOSSES RFL IN db (part d)"
440  INPUT RFL : PRINT : PRINT " 16. RFL=";RFL;"db"
450  PRINT : PRINT " ENTER THE ILLUMINATION EFFICIENCY r1 (part d)"
460  INPUT r1 : PRINT : PRINT " 17. r1=";r1
470  PRINT : PRINT " ENTER THE CROSSOVER LOSSE Lco IN db"
480  INPUT Lco : PRINT : PRINT " 18. Lco=";Lco;"db"
490  PRINT : PRINT " IS THE INPUT DATA CORRECT Y/N?"
500  INPUT A$
510  IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y"  THEN 1150
520  PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
530  PRINT : PRINT " 1. OUTPUT PEAK POWER?"
540  PRINT : PRINT " 2. THE BORESIGHT ANTENNA GAIN?"
550  PRINT : PRINT " 3. THE OPERATING FREQ.?"
560  PRINT : PRINT " 4. THE RF LOSSES?"
570  PRINT : PRINT " 5. THE RECEIVER'S NOISE BANDWIDTH?"
580  PRINT : PRINT " 6. THE RECEIVER'S NOISE FIGURE?"
590  PRINT : PRINT " 7. THE PULSE WIDTH?"
600  PRINT : PRINT " 8. THE P.R.F?"
610  PRINT : PRINT " 9. THE INTEGRATION TIME?"
620  PRINT : PRINT " 10. THE WEATHER ATTENUATION?"
630  PRINT : PRINT " 11. THE SKY TEMPERATURE?"
640  PRINT : PRINT " 12. THE TARGET'S RCS?"
650  PRINT : PRINT " 13. THE PENCIL BEAMWIDTH?"
660  PRINT : PRINT " 14. THE (J/S) RATIO?"
670  PRINT : PRINT " 15. THE RANGE?"
680  PRINT : PRINT " 16. THE RF LOSSES for part c?"
690  PRINT : PRINT " 17. THE ILLUMINATION EFFICIENCY?"
700  PRINT : PRINT " 18. THE CROSSOVER LOSS?"
710  INPUT C$
```

```
720  IF C$="1"  THEN PRINT : PRINT " ENTER THE OUTPUT PEAK POWER Pt IN W"
730  IF C$="1"  THEN INPUT Pt : PRINT : PRINT " 1. Pt=";Pt;"W" : GOTO 1090
740  IF C$="2"  THEN PRINT : PRINT " ENTER THE BORESIGHT ANTENNA GAIN Gt IN db"
750  IF C$="2"  THEN INPUT Gt : PRINT : PRINT " 2. Gt=";Gt;"db" : GOTO 1090
760  IF C$="3"  THEN PRINT : PRINT " ENTER THE OPERATING FREQ. f0 in GHz"
770  IF C$="3"  THEN INPUT f0 : PRINT : PRINT " 3. f0=";f0;"GHz" : GOTO 1090
780  IF C$="4"  THEN PRINT : PRINT " ENTER THE RF LOSSES Lp IN db"
790  IF C$="4"  THEN INPUT Lp : PRINT : PRINT " 4. Lp=";Lp;"db" : GOTO 1090
800  IF C$="5"  THEN PRINT : PRINT " ENTER THE RECEIVER NOISE BANDWIDTH Bn IN MHz"
820  IF C$="5"  THEN INPUT Bn : PRINT : PRINT " 5. Bn=";Bn;"MHz" : GOTO 1090
830  IF C$="6"  THEN PRINT : PRINT " ENTER THE RECEIVER NOISE FIGURE F IN db"
840  IF C$="6"  THEN INPUT F : PRINT : PRINT " 6. F=";f;"db" : GOTO 1090
850  IF C$="7"  THEN PRINT : PRINT " ENTER THE PULSE WIDTH T IN ns"
860  IF C$="7"  THEN INPUT T : PRINT : PRINT " 7. T=";T;"ns" : GOTO 1090
870  IF C$="8"  THEN PRINT : PRINT " ENTER THE P.R.F fp IN KHz"
880  IF C$="8"  THEN INPUT fp : PRINT : PRINT " 8. fp=";fp;"KHz" : GOTO 1090
890  IF C$="9"  THEN PRINT : PRINT " ENTER THE INTEGRATION TIME TI IN msec."
900  IF C$="9"  THEN INPUT T1 : PRINT : PRINT " 9. T1=";T1;"msec." : GOTO 1090
910  IF C$="10" THEN PRINT : PRINT "ENTER THE WEATHER ATTENUATION At IN db/KM"
920  IF C$="10" THEN INPUT At : PRINT : PRINT " 10. At=";At;"db/KM" : GOTO 1090
930  IF C$="11" THEN PRINT : PRINT " ENTER THE SKY TEMPERATURE Ta IN KELVIN"
940  IF C$="11" THEN INPUT Ta : PRINT : PRINT " 11. Ta=";Ta;"KELVIN" : GOTO 1090
950  IF C$="12" THEN PRINT : PRINT " ENTER THE TARGET RCS IN dbsm"
960  IF C$="12" THEN INPUT RCS : PRINT : PRINT " 12. RCS=";RCS;"dbsm" : GOTO 1090
970  IF C$="13" THEN PRINT : PRINT " ENTER THE DEG. OF THE PENCIL BEAM PB (part b)"
980  IF C$="13" THEN INPUT PB : PRINT : PRINT " 13. PB=";PB;"Deg." : GOTO 1090
990  IF C$="14" THEN PRINT : PRINT " ENTER THE (J/S) JS IN db (part b)"
1000 IF C$="14" THEN INPUT JS : PRINT : PRINT " 14. (J/S)=";JS;"db" : GOTO 1090
1010 IF C$="15" THEN PRINT : PRINT " ENTER THE RANGE R IN KM (part c)"
1020 IF C$="15" THEN INPUT R : PRINT : PRINT " 15. R=";R;"KM" : GOTO 1090
1030 IF C$="16" THEN PRINT : PRINT " ENTER THE RF LOSSES RFL IN db (part d)"
1040 IF C$="16" THEN INPUT RFL : PRINT : PRINT " 16. RFL=";RFL;"db" : GOTO 1090
1050 IF C$="17" THEN PRINT : PRINT " ENTER THE ILLUMINATION EFFICIENCY r1 (part d)"
1060 IF C$="17" THEN INPUT r1 : PRINT : PRINT " 17. r1=";r1 : GOTO 1090
1070 IF C$="18" THEN PRINT : PRINT " ENTER THE CROSSOVER LOSSE Lco IN db"
```

```
1080  IF C$="18" THEN INPUT Lco : PRINT : PRINT " 18. Lco=";Lco;"db" : GOTO 1090
1090  PRINT : PRINT " IS EVERYTHING O.K NOW?"
1100  INPUT B$
1110  IF LEFT$(B$,1)="Y" OR LEFT$(B$,1)="y"  THEN 1150
1120  PRINT : PRINT " WHAT DO YOU WANT TO CHANGE AGAIN?"
1130  PRINT : PRINT " HIT ANY KEY IN YOUR KEYBOARD AND EVERYTHING WILL WORK FOR YOU
MALAKA"
1140  INPUT F$  : GOTO 530
1150  RETURN
1160 '*********************************
1170  '      PRINTS THE INPUT DATA
1180 '*********************************
1190  LPRINT : LPRINT TAB(30); " PROBLEM #3"
1200  LPRINT TAB(30); " ----------"
1210  LPRINT : LPRINT " G I V E N"
1220  LPRINT " ---------"
1230  LPRINT : LPRINT " 1. Pt=";Pt;"W" SPC(10); " : OUTPUT PEAK POWER"
1240  LPRINT : LPRINT " 2. Gt=";Gt;"db" SPC(8); " : BORESIGHT ANTENNA GAIN"
1250  LPRINT : LPRINT " 3. f0=";f0;"GHz" SPC(5); " : OPERATING FREQ."
1260  LPRINT : LPRINT " 4. Lp=";Lp;"db" SPC(9); " : RF LOSSES"
1270  LPRINT : LPRINT " 5. Bn=";Bn;"MHz" SPC(6); " : RECEIVER NOISE BANDWIDTH"
1280  LPRINT : LPRINT " 6. F=";f;"db" SPC(9); " : RECEIVER NOISE FIGURE"
1290  LPRINT : LPRINT " 7. T=";T;"ns" SPC(9); " : PULSE WIDTH"
1300  LPRINT : LPRINT " 8. fp=";fp;"KHz" SPC(6); " : P.R.F"
1310  LPRINT : LPRINT " 9. T1=";T1;"msec." SPC(5); " : INTEGRATION TIME"
1320  LPRINT : LPRINT " 10. At=";At;"db/KM" SPC(4); " : WEATHER ATTENUATION"
1330  LPRINT : LPRINT " 11. Ta=";Ta;"KELVIN" SPC(2); " : SKY TEMPERATURE"
1340  LPRINT : LPRINT " 12. RCS=";RCS;"dbsm" SPC(2); " : TARGET RCS"
1350  LPRINT : LPRINT " 13. PB=";PB;"Deg." SPC(5); " : DEG. OF THE PENCIL BEAM"
1360  LPRINT : LPRINT " 14. (J/S)=";JS;"db" SPC(4); " : (J/S)"
1370  LPRINT : LPRINT " 15. R=";R;"KM" SPC(9); " : RANGE"
1380  LPRINT : LPRINT " 16. RFL=";RFL;"db" SPC(7); " : RF LOSSES for part d"
1390  LPRINT : LPRINT " 17. r1=";r1 SPC(9); " : ILLUMINATION EFFICIENCY"
1400  LPRINT : LPRINT " 18. Lco=";Lco;"db" SPC(7);" : CROSSOVER LOSS"
1410  RETURN
```

```
1420 '*************************************
1430  ' SUBRUTINE THAT CONVERTS UNITS
1440 '*************************************
1450  LET M=.4342945#
1460  LET PI=3.14159 :  C=3*10^8
1470  LET f0=f0*10^9 : fp=fp*10^3
1480  LET R=R*10^3 : l=C/f0
1490  LET Gt1=Gt/10: Gt2=CINT(10^Gt1)
1500  LET Lp1=Lp/10: Lp2=10^Lp1
1510  LET RCS1=RCS/10: RCS2=CSNG(10^RCS1)
1520  LET re=10^(-1/10)
1530  LET Gtot=Gt+RFL: Gtot1=Gtot/10: Gtot2=CINT(10^Gtot1)
1540  LET Lco1=Lco/10: Lco2=CSNG(10^(-Lco1))
1550  LET Gd=Gt+RFL+Lco
1560  LET Gd1=Gd/10: Gd2=10^Gd1
1570  RETURN
1580 '*************************************
1590  ' PRINTS THE RESULTS
1600 '*************************************
1610  PRINT : PRINT : PRINT " PART (a) :"
1620  PRINT " ----------"
1630  LPRINT : LPRINT : LPRINT " PART (a) :"
1640  LPRINT " ----------"
1650  LET Ru=c/(2*fp)*(1/1000)
1660  PRINT : PRINT " a. Ru=";Ru;"KM"; " : MAX. UNAMBIGUOUS RANGE"
1670  LPRINT : LPRINT " a. Ru=";Ru;"KM"; " : MAX. UNAMBIGUOUS RANGE"
1680  PRINT : PRINT : PRINT " PART (b) :"
1690  PRINT " ----------"
1700  LPRINT : LPRINT : LPRINT " PART (b) :"
1710  LPRINT " ----------"
1720  LET G=41250!/(PB^2) : Ae=1^2*G/(4*PI)
1730  LET Ge=JS*(Lp2^2)*RCS2/(Ae*G)
1740  LET Ge1=CSNG(10*M*LOG(Ge))
1750  PRINT : PRINT " b. Ge=";Ge1; "db"; " : REPEATER GAIN REQUIRED FOR (J/S)=";JS;"db"
1760  LPRINT : LPRINT " b. Ge=";Ge1;"db"; " : REPEATER GAIN REQUIRED FOR (J/S)=";JS;"db"
```

```
1770  PRINT : PRINT : PRINT " PART (c) :"
1780  PRINT " ----------"
1790  LPRINT : LPRINT : LPRINT " PART (c) :"
1800  LPRINT " ----------"
1810 LET Pout=Pt*Gt2*(10^(-At/10))*Ae*Ge/(4*PI*R^2*Lp2)
1820  LET Pout=CSNG(Pout*1000)      'mW
1830  PRINT : PRINT " c. Pout=";Pout;"mW"; " : JAMMER OUTPUT POWER"
1840  LPRINT : LPRINT " c. Pout=";Pout;"mW"; " : JAMMER OUTPUT POWER"
1850  PRINT : PRINT : PRINT " PART (d) :"
1860  PRINT " ----------"
1870  LPRINT : LPRINT : LPRINT " PART (d) :"
1880  LPRINT " ----------"
1890  LET D=CSNG(1/PI*SQR(Gtot2/(ra*rl))*100)     'cm
1900  PRINT : PRINT " d. D=";D;"cm"; " : DIAMETER OF THE SEEKER DISH ANTENNA"
1910  LPRINT : LPRINT " d. D=";D;"cm"; " : DIAMETER OF THE SEEKER DISH ANTENNA"
1920  PRINT : PRINT : PRINT " PART (e) :"
1930  PRINT " ----------"
1940  LPRINT : LPRINT : LPRINT " PART (e) :"
1950  LPRINT " ----------"
1960  LET THb=SQR(41253!/Gd2)
1970 LET THq=((LOG(Lco2))/(-2.776))^(1/2)*THb:THq=CSNG(THq)
1980  PRINT : PRINT " e. THq=";THq;"Deg."; " : SQUINT ANGLE"
1990  LPRINT : LPRINT " e. THq=";THq;"Deg."; " : SQUINT ANGLE"
2000  RETURN
```

## PROBLEM#3

GIVEN

1. Pt= 1 W : OUTPUT PEAK POWER
2. Gt= 38 db : BORESIGHT ANTENNA GAIN
3. f0= 93.7 GHz : OPERATING FREQ.
4. Lp= 3 db : RF LOSSES
5. Bn= 500 MHz : RECEIVER NOISE BANDWIDTH
6. F= 11 db : RECEIVER NOISE FIGURE
7. T= 50 ns : PULSE WIDTH
8. fp= 100 KHz : P.R.F
9. Ti= 50 msec. : INTEGRATION TIME
10. At= .4 db/KM : WEATHER ATTENUATION
11. Ta= 270 KELVIN : SKY TEMPERATURE
12. RCS= 14.8 dbsm : TARGET RCS
13. PB= 10 Deg. : DEG. OF THE PENCIL BEAM
14. (J/S)= 10 db : (J/S)
15. R= 1 KM : RANGE
16. RFL= 1 db : RF LOSSES for part d
17. ri= .6 : ILLUMINATION EFFICIENCY
18. Lco= 1 db : CROSSOVER LOSS

PART (a):

a. Ru= 1.5 KM : MAX. UNAMBIGUOUS RANGE

PART (b):

b. Ge= 39.376 db : REPEATER GAIN REQUIRED FOR (J/S)= 10 db

PART (c):

c. Pout= .668953 mW : JAMMER OUTPUT POWER

PART (d):

D= 13.1568 cm : DIAMETER OF THE SEEKER DISH ANTENNA

PART (e):

e. THq= .58496 Deg. : SQUINT ANGLE

```
10    PRINT : PRINT TAB(30); " PROBLEM #4"
20    PRINT TAB(30); " ---------"
30    GOSUB 100 : GOSUB 1050 : GOSUB 1300
40    GOSUB 1480 : GOSUB 1640 : GOSUB 1800 : GOSUB 1960
50    PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
60     INPUT D$
70     IF LEFT$(D$,1)="Y" OR LEFT$(D$,1)="y"  THEN 30
80     END
90    '**********************************
100   '          INPUTS THE DATA
110   '**********************************
120   PRINT : PRINT " ENTER THE ARRAY SIZE d1,d2 IN METERS"
130   INPUT d1,d2 : PRINT : PRINT " 1. d1xd2=";d1"x"d2" m"
140   PRINT : PRINT " ENTER THE OPERATING FREQ. f0 IN GHz"
160   INPUT f0 : PRINT : PRINT " 2. f0=";f0;"GHZ"
170   PRINT : PRINT " ENTER THE FEED & PHASE SHIFTER LOSSES Lfp IN db"
180   INPUT Lfp : PRINT : PRINT " 3. Lfp=";Lfp;"db"
190   PRINT : PRINT " ENTER THE SIDELOBE LEVEL S.L IN db"
200   INPUT S.L : PRINT : PRINT " 4. S.L=";S.L;"db"
210   PRINT : PRINT " ENTER THE ILLUMINATION EFFICIENCY r1"
220   INPUT r1 : PRINT : PRINT " 5. r1=";r1
230   PRINT : PRINT " ENTER THE OUTPUT POWER Pa IN Mw"
240   INPUT Pa : PRINT : PRINT " 6. Pa=";Pa;"Mw"
250   PRINT : PRINT " ENTER THE VALUE OF THE TWO T.W"
260   INPUT T.W : PRINT : PRINT " 7. T.W=";T.W
270   PRINT : PRINT " ENTER THE WEIGHTING FILTER LOSS Lm IN db"
280   INPUT Lm : PRINT : PRINT " 8. Lm=";Lm;"db"
290   PRINT : PRINT " ENTER THE VALUE OF THE MIN. OUTPUT FOR AUTOMATIC DETECTION,S I IN
 db"
```

```
300   INPUT S1: PRINT : PRINT " 9. (S/N)min=";S1;"db"
310   PRINT : PRINT " ENTER THE R.C.S OF THE CRUISE MISSILES Sav IN dbsm"
320   INPUT Sav : PRINT : PRINT " 10. Sav=";Sav;"dbsm"
330   PRINT : PRINT " ENTER THE RANGE OF THE TWO NOISE JAMMERS R IN KM"
340   INPUT R : PRINT : PRINT " 11. R=";R;"KM"
350   PRINT : PRINT " ENTER THE #OF CARCINOTRONS THAT EACH JAMMER CARRIES Cr"
360   INPUT Cr : PRINT : PRINT " 12. Cr=";Cr
370   PRINT : PRINT " ENTER THE ERP Pj IN KW"
380   INPUT Pj : PRINT : PRINT " 13. Pj=";Pj;"KW/tube"
390   PRINT : PRINT " ENTER THE PROPAGATION FACTOR g"
400   INPUT g : PRINT : PRINT " 14. g=";g
410   PRINT : PRINT "NOW GO TO PART c&e OF THE PROBLEM AND ENTER THE FOLLOWING :"
420   PRINT : PRINT " ENTER THE RANGE THAT THE CRUISE MISSILE IS ILLUMINATED R1 IN KM"
430   INPUT R1 : PRINT : PRINT " 15. R1=";R1;"KM"
450   PRINT : PRINT " ENTER AGAIN THE RANGE THAT THE CRUISE MISSILE IS ILLUMINATED R2 IN
 KM (for part e)"
460   INPUT R2 : PRINT : PRINT " 16. R2=";R2;"KM"
470   PRINT : PRINT " ENTER THE INTEGRATION EFFICIENCY E1"
480   INPUT E1 : PRINT : PRINT " 17. E1(n)=";E1
490   PRINT : PRINT " IS THE INPUT DATA CORRECT Y/N?"
500   INPUT A$
510   IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y" THEN 1030
520   PRINT : PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
530   PRINT : PRINT " 1. THE SIZE OF THE ARRAY?", " 2. THE OPERATING FREQ.?"
540   PRINT : PRINT " 3. THE FEED AND PHASE SHIFTER LOSSES?", " 4. THE SIDELOBE LEVEL?"
550   PRINT : PRINT " 5. THE ILLUMINATION EFFICIENCY?", " 6. THE OUTPUT POWER?"
560   PRINT : PRINT " 7. THE VALUE OF THE TWO TW?", " 8. THE WEIGHTING FILTER LOSS?"
570   PRINT : PRINT " 9. THE VALUE OF THE (S/N)min?", " 10. THE RCS OF THE CRUISE MISSILE?"
580   PRINT : PRINT " 11. THE RANGE OF THE TWO NOISE JAMMERS?",
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590   PRINT : PRINT " 12. THE #OF CANCINOTRONS?", " 13. THE ERP?"
600   PRINT : PRINT " 14.THE PROPAGATION FACTOR?", " 15. THE RANGE OF THE CRUISE MISSILE
 (partc)?"
610   PRINT : PRINT " 16. THE RANGE OF THE CRUISE MISSILE (part e)?", " 17. THE INTEGRATION
 EFFICIENCY?"
620   INPUT C$
630   IF C$="1"  THEN   PRINT : PRINT " ENTER THE ARRAY SIZE d1,d2 IN METERS"
640   IF C$="1"  THEN   INPUT d1,d2 : PRINT : PRINT " 1. d1xd2=";d1"x"d2" m" : GOTO 970
650   IF C$="2"  THEN   PRINT : PRINT " ENTER THE OPERATING FREQ. f0 IN GHz"
660   IF C$="2"  THEN   INPUT f0 : PRINT : PRINT " 2. f0=";f0;"GHZ" : GOTO 970
670   IF C$="3"  THEN   PRINT : PRINT " ENTER THE FEED & PHASE SHIFTER LOSSES Lfp IN db"
680   IF C$="3"  THEN   INPUT Lfp : PRINT : PRINT " 3. Lfp=";Lfp;"db" : GOTO 970
690   IF C$="4"  THEN   PRINT : PRINT " ENTER THE SIDELOBE LEVEL S.L IN db"
700   IF C$="4"  THEN   INPUT S.L : PRINT : PRINT " 4. S.L=";S.L;"db" : GOTO 970
710   IF C$="5"  THEN   PRINT : PRINT " ENTER THE ILLUMINATION EFFICIENCY ri"
720   IF C$="5"  THEN   INPUT ri : PRINT : PRINT " 5. ri=";ri : GOTO 970
730   IF C$="6"  THEN   PRINT : PRINT " ENTER THE OUTPUT POWER Pe IN Mw"
740   IF C$="6"  THEN   INPUT Pe : PRINT : PRINT " 6. Pe=";Pe;"Mw" : GOTO 970
750   IF C$="7"  THEN   PRINT : PRINT " ENTER THE VALUE OF THE TWO T.W"
760   IF C$="7"  THEN   INPUT T.W : PRINT : PRINT " 7. T.W=";T.W : GOTO 970
770   IF C$="8"  THEN   PRINT : PRINT " ENTER THE WEIGHTING FILTER LOSS Lm IN db"
780   IF C$="8"  THEN   INPUT Lm : PRINT : PRINT " 8. Lm=";Lm;"db" : GOTO 970
790   IF C$="9"  THEN   PRINT : PRINT " ENTER THE VALUE OF THE MIN. OUTPUT FOR
 AUTOMATIC DETECTION,S1 IN db"
800   IF C$="9"  THEN   INPUT S1: PRINT : PRINT " 9. (S/N)min=";S1;"db" : GOTO 970
810   IF C$="10" THEN   PRINT : PRINT " ENTER THE R.C.S OF THE CRUISE MISSILES Sav IN
 dbsm"
820   IF C$="10" THEN   INPUT Sav : PRINT : PRINT " 10. Sav=";Sav;"dbsm" : GOTO 970
830   IF C$="11" THEN   PRINT : PRINT " ENTER THE RANGE OF THE TWO NOISE JAMMERS R IN
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 KM"
840   IF C$="11" THEN    INPUT R : PRINT : PRINT " 11. R=";R;"KM" : GOTO 970
850   IF C$="12" THEN    PRINT : PRINT " ENTER THE #OF CARCINOTRONS THAT EACH JAMMER
 CARRIESCr"
860   IF C$="12" THEN    INPUT Cr : PRINT : PRINT " 12. Cr=";Cr : GOTO 970
870   IF C$="13" THEN    PRINT : PRINT " ENTER THE ERP Pj IN KW"
880   IF C$="13" THEN    INPUT Pj : PRINT : PRINT " 13. Pj=";Pj;"KW/tube" : GOTO 970
890   IF C$="14" THEN    PRINT : PRINT " ENTER THE PROPAGATION FACTOR g"
900   IF C$="14" THEN    INPUT g : PRINT : PRINT " 14. g=";g : GOTO 970
910   IF C$="15" THEN    PRINT : PRINT " ENTER THE RANGE THAT THE CRUISE MISSILE IS
 ILLUMINATED R1 IN KM"
920   IF C$="15" THEN    INPUT R1 : PRINT : PRINT " 15. R1=";R1;"KM" : GOTO 970
930   IF C$="16" THEN    PRINT : PRINT " ENTER AGAIN THE RANGE THAT THE CRUISE MISSILE
 IS ILLUMINATED R2 IN KM (for part e)"
940   IF C$="16" THEN    INPUT R2 : PRINT : PRINT " 16. R2=";R2;"KM" : GOTO 970
950   IF C$="17" THEN    PRINT : PRINT " ENTER THE INTEGRATION EFFICIENCY E1"
960   IF C$="17" THEN    INPUT E1 : PRINT : PRINT " 17. E1(n)=";E1 : GOTO 970
970   PRINT : PRINT " IS EVERYTHING O.K NOW?"
980   INPUT B$
990   IF LEFT$(B$,1)="Y" OR LEFT$(B$,1)="y" THEN 1030
1000  PRINT : PRINT " WHAT DO YOU WANT TO CHANGE AGAIN?"
1010  PRINT : PRINT " HIT ANY KEY IN YOUR KEYBOARD AND EVERYTHING WILL WORK FOR YOU
 MALAKA"
1020   INPUT F$   : GOTO 530
1030  RETURN
1040'**********************************
1050  '       PRINTS THE INPUT DATA
1060'**********************************
1070  LPRINT : LPRINT TAB(30);" PROBLEM #4"
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1080 LPRINT TAB(30);" ----------"
1090 LPRINT : LPRINT " G I V E N"
1100 LPRINT " ---------"
1110 LPRINT : LPRINT " 1. d1xd2=";d1"x"d2" m" TAB(20); " : ARRAY SIZE"
1120 LPRINT : LPRINT " 2. f0=";f0;"GHZ"TAB(20);" : OPERATING FREQ."
1130 LPRINT : LPRINT " 3. Lfp=";Lfp;"db" TAB(20);" : FEED & PHASE SHIFTER LOSSES"
1140 LPRINT : LPRINT " 4. S.L=";S.L;"db" TAB(20);" : SIDELOBE LEVEL"
1150 LPRINT : LPRINT " 5. ri=";ri TAB(20); " : ILLUMINATION EFFICIENCY"
1160 LPRINT : LPRINT " 6. Pa=";Pa;"Mw" TAB(20); " : OUTPUT POWER"
1170 LPRINT : LPRINT " 7. T.W=";T.W TAB(20); " : VALUE OF THE TWO TW"
1180 LPRINT : LPRINT " 8. Lm=";Lm;"db" TAB(20);" : WEIGHTING FILTER LOSS"
1190 LPRINT : LPRINT " 9. (S/N)min=";S1;"db" TAB(20);" : (S/N)min FOR AUT. DETECTION"
1200 LPRINT : LPRINT " 10. Sav=";Sav;"dbsm" TAB(20);" : R.C.S FOR THE CRUISE MISSILE"
1210 LPRINT : LPRINT " 11. R=";R;"KM" TAB(20); " : RANGE OF THE TWO NOISE JAMMERS"
1220 LPRINT : LPRINT " 12. Cr=";Cr TAB(20); " : #OF CANCINOTRONS"
1230 LPRINT : LPRINT " 13. Pj=";Pj;"KW/tube" TAB(20);" : ERP VALUE"
1240 LPRINT : LPRINT " 14. g=";g TAB(20);" : PROPAGATION FACTOR"
1250 LPRINT : LPRINT " 15. R1=";R1;"KM" TAB(20);" : RANGE OF THE CRUISE MISSILE (part c)"
1260 LPRINT : LPRINT " 16. R2=";R2;"KM" TAB(20);" : RANGE OF THE CRUISE MISSILE (part e)"
1270 LPRINT : LPRINT " 17. Ei(n)=";Ei TAB(20); " : INTEGRATION EFFICIENCY"
1280 RETURN
1290'*****************************************
1300 ' CALCULATION AND PRINTOUT FOR PART e:
1310'*****************************************
1320 PRINT : PRINT : PRINT " PART e:"
1330 LPRINT : LPRINT : LPRINT " PART e:"
1340 PRINT " -------"
1350 LPRINT " -------"
1360 LET PI=3.14159 : f0=f0*10^9 : C=3*10^8
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```
1370 LET A=d1*d2
1380 LET l=C/f0
1390 LET Lfp1=10^(-Lfp/10)
1400 LET Ae=CSNG(A*Lfp1*r1)
1410 LET Gp=CINT(4*PI*Ae/(l^2))
1420 PRINT : PRINT " 1(a). Ae=A*Lfp1*r1=";Ae;"sq.m"; " : EFFECTIVE AREA OF THE PHASED
ARRAY"
1430 LPRINT : LPRINT " 1(a). Ae=A*Lfp1*r1=";Ae;"sq.m"; " : EFFECTIVE AREA OF THE PHASED
ARRAY"
1440 PRINT : PRINT " 2(a). Gp=4*PI*Ae/(l^2)=";Gp; " : POWER GAIN OF PHASED ARRAY"
1450 LPRINT : LPRINT " 2(a). Gp=4*PI*Ae/(l^2)=";Gp; " : POWER GAIN OF PHASED ARRAY"
1460 RETURN
1470'*****************************************
1480 ' CALCULATION AND PRINTOUT FOR PART b:
1490'*****************************************
1500 PRINT : PRINT : PRINT " PART b:"
1510 LPRINT : LPRINT : LPRINT " PART b:"
1520 PRINT " -------"
1530 LPRINT " -------"
1540 LET Pj=Pj*10^3
1550 LET Lm1=Lm/10 : Lm2=10^Lm1
1560 LET R=R*10^3
1570 LET J=CSNG(2*Cr*Pj*Ae/(4*PI*R^2*Lm2*T.W))
1580 LET J1=CSNG(10*.4342945**LOG(J)) 'dbw VALUE
1590 LET J2=CSNG(J1+30)          'dbm VALUE
1600 PRINT:PRINT " 1(b). J=Gj*Pj**Ae/(4*PI*R^2*Lm2*T.W)=";J;"W";" OR";J1;"dbW";" OR
";J2;"dbm"
1610 LPRINT : LPRINT " 1(b). J=Gj*Pj**Ae/(4*PI*R^2*Lm2)=";J;"W";" OR";J1;"dbW";"
OR";J2;"dbm"
```

```
1620 RETURN
1630'*****************************************
1640 ' CALCULATION AND PRINTOUT FOR PART c:
1650'*****************************************
1660 PRINT : PRINT : PRINT " PART c:"
1670 LPRINT : LPRINT : LPRINT " PART c:"
1680 PRINT " -------"
1690 LPRINT " -------"
1700 LET Pa=Pa*10^6
1710 LET S1ev=10^(-Sev/10)
1720 LET R1=R1*10^3
1730 LET S2=CSNG(Pa*Gp*S1ev*Ae/((4*PI*R1^2)^(2)))
1740 LET S3=CSNG(10*.4342945#*LOG(S2))    'dbw
1750 LET S4=CSNG(S3+30)   'dbm
1760 PRINT : PRINT " 1(c). S=Pa*Gp*S1ev*Ae/((4*PI*R1^2)^(2))=";S2;"W";" OR";S3;"dbW";" OR
";S4;"dbm";" : SINGLE PULSE ECHO SIGNAL POWER"
1770 LPRINT : LPRINT " 1(c). S=Pa*Gp*S1ev*Ae/((4*PI*R1^2)^(2))=";S2;"W";" OR";S3;"dbW";"
OR";S4;"dbm";" : SINGLE PULSE ECHO SIGNAL POWER"
1780 RETURN
1790'*****************************************
1800 ' CALCULATION AND PRINTOUT FOR PART d:
1810'*****************************************
1820 PRINT : PRINT : PRINT " PART d:"
1830 LPRINT : LPRINT : LPRINT " PART d:"
1840 PRINT " -------"
1850 LPRINT " -------"
1860 LET T.W1=10*.4342945#*LOG(T.W)
1870 LET B=CSNG(J2-S4)
1880 LET C=CSNG(-B+T.W1-Lm)
```

```
1890  LET C=-C
1900  PRINT : PRINT " 1(d). (J/S)In=J2-S4=";B;"dbm"; " : THE SINGLE PULSE (J/S) AT THE
 RECEIVERINPUT"
1910  LPRINT : LPRINT " 1(d). (J/S)In=J2-S4=";B;"dbm"; " : THE SINGLE PULSE (J/S) AT THE
 RECEIVERINPUT"
1920  PRINT : PRINT " 2(d). (S/J)out=(S/J)In+(T.W)-Lm=";C;"db"; " : THE SINGLE PULSE (J/S) AT
 THERECEIVER OUTPUT"
1930  LPRINT :LPRINT " 2(d). (S/J)out=(S/J)In+(T.W)-Lm=";C;"dbm"; " : THE SINGLE PULSE (J/S)
 AT THE RECEIVER OUTPUT"
1940  RETURN
1950**********************************************
1960  ' CALCULATION AND PRINTOUT FOR PART e:
1970**********************************************
1980  PRINT : PRINT : PRINT " PART e:"
1990  LPRINT : LPRINT : LPRINT " PART e:"
2000  PRINT " -------"
2010  LPRINT " -------"
2020  LET I1=S1+C
2030  LET I11=I1/10 : I12=10^I11
2040  PRINT : PRINT " 1(e). I1(n)=n=";CINT(I12); " : #OF PULSES INTEGR. IN PERFECT INTEGRATOR"
2050  LPRINT : LPRINT " 1(e). I1(n)=n=";CINT(I12);" : #OF PULSES INTEGR. IN PERFECT
 INTEGRATOR"
2060  RETURN
```

## PROBLEM*4

GIVEN

| | |
|---|---|
| 1. d1xd2= 3.65 x 3.65 m | : ARRAY SIZE |
| 2. f0= 3.3 GHZ | : OPERATING FREQ. |
| 3. Lfp= 2.5 db | : FEED & PHASE SHIFTER LOSSES |
| 4. S.L= 30 db | : SIDELOBE LEVEL |
| 5. ri= .5 | : ILLUMINATION EFFICIENCY |
| 6. Pa= 4 MW | : OUTPUT POWER |
| 7. T.W= 1000 | : VALUE OF THE TWO TW |
| 8. Lm= 3 db | : WEIGHTING FILTER LOSS |
| 9. (S/N)min= 13 db | : (S/N)min FOR AUT. DETECTION |
| 10. Sav= 3 dbsm | : R.C.S FOR THE CRUISE MISSILE |
| 11. R= 100 KM | : RANGE OF THE TWO NOISE JAMMERS |
| 12. Cr= 18 | : *OF CANCINOTRONS |
| 13. Pj= 10 KW/tube | : ERP VALUE |
| 14. g= 1 | : PROPAGATION FACTOR |
| 15. R1= 80 KM | : RANGE OF THE CRUISE MISSILE (part c) |
| 16. R2= 80 KM | : RANGE OF THE CRUISE MISSILE (part e) |
| 17. Ei(n)= 1 | : INTEGRATION EFFICIENCY |

PART a:

1(a). Ae=A*Lfp1*ri= 3.7459 sq.m: EFFECTIVE AREA OF THE PHASED ARRAY

2(a). Gp=4*PI*Ae/(1^2)= 5696 : POWER GAIN OF PHASED ARRAY

PART b:

1(b). J=Gj*Pj**Ae/(4*PI*R^2*Lm2*T.W)=5.37835 E-09 W OR-82.6935 dbw OR -52.6935 dbm

PART c:

1(c). S=Pa*Gp*Slav*Ae/((4*PI*R1^2)^(2))= 6.61313D-12 W OR - 111.796 dbw OR -81.796 dbm

SINGLE PULSE ECHO SIGNAL POWER

PART d:

1(d). (J/S)in=J2-S4= 29.1025 dbm : THE SINGLE PULSE (J/S) AT THE RECEIVER INPUT

2(d). (S/J)out=(S/J)in+(T.W)-Lm= 2.1025 db : THE SINGLE PULSE (J/S) AT THE RECEIVER OUTPUT

PART e:

1(e). II(n)=n= 32 : #OF PULSES INTEGR. IN PERFECT INTEGRATOR

```
10   PRINT : PRINT TAB(30); " PROBLEM #8"
20   PRINT TAB(30); " ----------"
30   GOSUB 100 : GOSUB 1020 : GOSUB 1250
40   GOSUB 1410 : GOSUB 1680 : GOSUB 1690
50   PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
60    INPUT D$
70   IF LEFT$(D$,1) ="Y" OR LEFT$(D$,1)="y"   THEN 30
80    END
90   '*********************************
100   '          INPUTS THE DATA
110  '*********************************
120  PRINT: PRINT " ENTER THE RANGE OF THE OPERATING FREQ. f10,f20 IN GHz"
130  INPUT f10,f20 : PRINT : PRINT " 1. f10=";f10,"f20=";f20;"GHz"
140  PRINT : PRINT " ENTER THE PEAK POWER Pp IN KW"
150  INPUT Pp : PRINT : PRINT " 2. Pp=";Pp;"KW"
160  PRINT : PRINT " ENTER THE PRF fp IN Hz"
170  INPUT fp : PRINT : PRINT " 3. fp=";fp;"Hz"
180  PRINT : PRINT " ENTER THE PULSEWIDTH T IN nsec."
190  INPUT T : PRINT : PRINT " 4. T=";T;"nsec."
200  PRINT : PRINT " ENTER THE ANTENNA GAIN Ga IN db"
210  INPUT Ga : PRINT : PRINT " 5. Ga=";Ga;"db"
220  PRINT : PRINT " ENTER THE AZIMUTH BEAMWIDTH A.B IN Deg."
230  INPUT A.B : PRINT : PRINT " 6. A.B=";A.B;"Deg."
240  PRINT : PRINT " ENTER THE ANTENNA SCAN RATE Wm IN RPM"
250  INPUT Wm : PRINT : PRINT " 7. Wm=";Wm;"RPM"
260  PRINT : PRINT " ENTER THE PLUMBING LOSSES Lp IN db"
270  INPUT Lp : PRINT : PRINT " 8. Lp=";Lp;"db"
280  PRINT : PRINT " ENTER THE Rx NOISE FIGURE Rx IN db"
290  INPUT Rx : PRINT : PRINT " 9. Rx=";Rx;"db"
300  PRINT : PRINT " ENTER THE AIRCRAFT'S ALTITUDE Ha IN ft"
310  INPUT Ha : PRINT : PRINT " 10. Ha=";Ha;"ft"
320  PRINT : PRINT " ENTER THE RANGE TO SUBMARINE Rs IN Kyards"
330  INPUT Rs : PRINT : PRINT " 11. Rs=";Rs;"Kyards"
340  PRINT : PRINT " ENTER THE PERISCOPE RCS IN sq. m"
350  INPUT RCS : PRINT : PRINT " 12. RCS=";RCS;"sq.m"
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```
360  PRINT : PRINT " NOW GO TO PART (a) AND INPUT : "
370  PRINT : PRINT " ENTER THE AVERAGE DURATION OF THE SEA CLUTTER SPIKES t1fa IN sec."
380  INPUT t1fa : PRINT : PRINT " 13. t1fa=";t1fa;"sec."
390  PRINT : PRINT " ENTER THE FALSE ALARM TIME Tfa IN sec."
400  INPUT Tfa : PRINT : PRINT " 14. Tfa=";Tfa;"sec."
410  PRINT : PRINT " NOW FROM PART (d) INPUT :"
420  PRINT : PRINT " ENTER THE POST DETECTION INTEGRATION PERIOD Ts IN sec."
430  INPUT Ts : PRINT : PRINT " 15. Ts=";Ts;"sec."
440  PRINT : PRINT " IS THE INPUT DATA CORRECT Y/N?"
450  INPUT A$
460  IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y"  THEN 1000
470  PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
480  PRINT : PRINT " 1. THE RANGE OF THE OPERATING FREQ.?"
490  PRINT : PRINT " 2. THE PEAK POWER?"
500  PRINT : PRINT " 3. THE P.R.F?"
510  PRINT : PRINT " 4. THE PULSEWIDTH?"
520  PRINT : PRINT " 5. THE ANTENNA GAIN?"
530  PRINT : PRINT " 6. THE AZIMUTH BEAMWIDTH?"
540  PRINT : PRINT " 7. THE ANTENNA SCAN RATE?"
550  PRINT : PRINT " 8. THE PLUMBING LOSSES?"
560  PRINT : PRINT " 9. THE Rx NOISE FIGURE?"
570  PRINT : PRINT " 10. THE AIRCRAFT'S ALTITUDE?"
580  PRINT : PRINT " 11. THE RANGE TO SUBMARINE?"
590  PRINT : PRINT " 12. THE PERISCOPE RCS?"
600  PRINT : PRINT " 13. THE AVERAGE DURATION OF THE SPIKES?"
610  PRINT : PRINT " 14. THE FALSE ALARM TIME?"
620  PRINT : PRINT " 15. THE POST DETECTION INTEGRATION PERIOD?"
630  INPUT C$
640  IF C$="1"  THEN PRINT : PRINT " ENTER THE RANGE OF THE OPERATING FREQ. f10,f20 IN
 GHz"
650  IF C$="1"  THEN INPUT f10,f20 : PRINT : PRINT " 1. f10=";f10,"f20=";f20;"GHz" : GOTO 940
660  IF C$="2"  THEN PRINT : PRINT " ENTER THE PEAK POWER Pp IN KW"
670  IF C$="2"  THEN INPUT Pp : PRINT : PRINT " 2. Pp=";Pp;"KW" : GOTO 940
680  IF C$="3"  THEN PRINT : PRINT " ENTER THE PRF fp IN Hz"
690  IF C$="3"  THEN INPUT fp : PRINT : PRINT " 3. fp=";fp;"Hz" : GOTO 940
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```
700   IF C$="4"  THEN PRINT : PRINT " ENTER THE PULSEWIDTH T IN nsec."
710   IF C$="4"  THEN INPUT T : PRINT : PRINT " 4. T=";T;"nsec." : GOTO 940
720   IF C$="5"  THEN PRINT : PRINT " ENTER THE ANTENNA GAIN Ga IN db"
730   IF C$="5"  THEN INPUT Ga : PRINT : PRINT " 5. Ga=";Ga;"db" : GOTO 940
740   IF C$="6"  THEN PRINT : PRINT " ENTER THE AZIMUTH BEAMWIDTH A.B IN Deg."
750   IF C$="6"  THEN INPUT A.B : PRINT : PRINT " 6. A.B=";A.B;"Deg." : GOTO 940
760   IF C$="7"  THEN PRINT : PRINT " ENTER THE ANTENNA SCAN RATE Wm IN RPM"
770   IF C$="7"  THEN INPUT Wm : PRINT : PRINT " 7. Wm=";Wm;"RPM" : GOTO 940
780   IF C$="8"  THEN PRINT : PRINT " ENTER THE PLUMBING LOSSES Lp IN db"
790   IF C$="8"  THEN INPUT Lp : PRINT : PRINT " 8. Lp=";Lp;"db" : GOTO 940
800   IF C$="9"  THEN PRINT : PRINT " ENTER THE Rx NOISE FIGURE Rx IN db"
810   IF C$="9"  THEN INPUT Rx : PRINT : PRINT " 9. Rx=";Rx;"db" : GOTO 940
820   IF C$="10"  THEN PRINT : PRINT " ENTER THE AIRCRAFT'S ALTITUDE Ha IN ft."
830   IF C$="10"  THEN INPUT Ha : PRINT : PRINT " 10. Ha=";Ha;"ft" : GOTO 940
840   IF C$="11"  THEN PRINT : PRINT " ENTER THE RANGE TO SUBMARINE Rs IN Kyards"
850   IF C$="11"  THEN INPUT Rs : PRINT : PRINT " 11. Rs=";Rs;"Kyards" : GOTO 940
860   IF C$="12"  THEN PRINT : PRINT " ENTER THE PERISCOPE RCS IN sq. m"
870   IF C$="12"  THEN INPUT RCS : PRINT : PRINT " 12. RCS=";RCS;"sq.m" : GOTO 940
880   IF C$="13"  THEN PRINT : PRINT " ENTER THE AVERAGE DURATION OF THE SEA CLUTTER
 SPIKES t1fa IN sec."
890   IF C$="13"  THEN INPUT t1fa : PRINT : PRINT " 13. t1fa=";t1fa;"sec." : GOTO 940
900   IF C$="14"  THEN PRINT : PRINT " ENTER THE FALSE ALARM TIME Tfa IN sec."
910   IF C$="14"  THEN INPUT Tfa : PRINT : PRINT " 14. Tfa=";Tfa;"sec." : GOTO 940
920   IF C$="15"  THEN PRINT : PRINT " ENTER THE POST DETECTION INTEGRATION PERIOD Ts IN
 sec."
930   IF C$="15"  THEN INPUT Ts : PRINT : PRINT " 15. Ts=";Ts;"sec." : GOTO 940
940   PRINT : PRINT " IS EVERYTHING O.K NOW?"
950   INPUT B$
960   IF LEFT$(B$,1)="Y" OR LEFT$(B$,1)="y"  THEN 1000
970   PRINT : PRINT " WHAT DO YOU WANT TO CHANGE AGAIN?"
980   PRINT : PRINT " HIT ANY KEY IN YOUR KEYBOARD AND EVERYTHING WILL WORK FOR YOU
 MALAKA"
990   INPUT F$  : GOTO 480
1000  RETURN
1010'*********************************
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1020 '       PRINTS THE INPUT DATA
1030'**********************************
1040 LPRINT : LPRINT TAB(30); " PROBLEM #8"
1050 LPRINT TAB(30);" ----------"
1060 LPRINT : LPRINT " G I V E N"
1070 LPRINT " ---------"
1080 LPRINT : LPRINT " 1. f10=";f10,"f20=";f20;"GHz" SPC(1);" : RANGE OF THE OPERATING
FREQ."
1090 LPRINT : LPRINT " 2. Pp=";Pp;"KW" SPC(10); " : PEAK POWER"
1100 LPRINT : LPRINT " 3. fp=";fp;"Hz" SPC(9); " : P.R.F"
1110 LPRINT : LPRINT " 4. T=";T;"nsec." SPC(8); " : PULSEWIDTH"
1120 LPRINT : LPRINT " 5. Ga=";Ga;"db" SPC(11); " : ANTENNA GAIN"
1130 LPRINT : LPRINT " 6. A.B=";A.B;"Deg." SPC(6); " : AZIMUTH BEAMWIDTH"
1140 LPRINT : LPRINT " 7. Wm=";Wm;"RPM" SPC(9); " : ANTENNA SCAN RATE"
1150 LPRINT : LPRINT " 8. Lp=";Lp;"db" SPC(12); " : PLUMBING LOSSES"
1160 LPRINT : LPRINT " 9. Rx=";Rx;"db" SPC(10); " : Rx NOISE FIGURE"
1170 LPRINT : LPRINT " 10. Ha=";Ha;"ft" SPC(8); " : AIRCRAFT'S ALTITUDE"
1180 LPRINT : LPRINT " 11. Rs=";Rs;"Kyards" SPC(6);" : RANGE TO SUBMARINE"
1190 LPRINT : LPRINT " 12. RCS=";RCS;"sq.m" SPC(8); " : PERISCOP'S RCS"
1200 LPRINT : LPRINT " 13. t1fa=";t1fa;"sec." SPC(7); " : AVERAGE DURATION OF THE SEA
CLUTTERSPIKES"
1210 LPRINT : LPRINT " 14. Tfa=";Tfa;"sec." SPC(6); " : FALSE ALARM TIME"
1220 LPRINT : LPRINT " 15. Ts=";Ts;"sec." SPC(9); " : POST DETECTION INTEGRATION PERIOD"
1230 RETURN
1240'*****************************************
1250 ' CALCULATION & PRINTOUT FOR PART (a)
1260'*****************************************
1270 PRINT : PRINT : PRINT " PART (a)"
1280 PRINT " --------"
1290 LPRINT : LPRINT : LPRINT " PART (a)"
1300 LPRINT " --------"
1310 LET Pfa=t1fa/Tfa
1320 PRINT : PRINT " FROM Fig. 13.5 (SKOLNIK Pg. 479) YOU CAN FIND THE THRESHOLD LEVEL
""TRSH"" SINCE YOU KNOW :"
1330 PRINT : PRINT " a. Pfa=";Pfa; " : PROBABILITY OF FALSE ALARM"
```

```
1340  INPUT " b. THE SEA STATE IS", K$
1350  PRINT : PRINT " ENTER THE THRESHOLD LEVEL REQUIRED TO ACHIEVE Pfa=";Pfa
1360  INPUT TRSH
1370  LPRINT : LPRINT " 1(a). Pfa=";Pfa; " : FALSE ALARM PROBABILITY"
1380  LPRINT : LPRINT " 2(a). THRESHOLD=";TRSH;"db"; " : LEVEL THAT THE THRESH. MUST BE SET
 ABOVE THE MEDIAN CLUTTER TO ACHIEVE Pfa=";Pfa
1390  RETURN
1400'*****************************************
1410  ' CALCULATION & PRINTOUT FOR PART (b)
1420'*****************************************
1430  PRINT : PRINT : PRINT " PART (b)"
1440  PRINT " --------"
1450  LPRINT : LPRINT : LPRINT " PART (b)"
1460  LPRINT " --------"
1470  LET C=3*10^8 :  PI=3.14159 :  f20=f20*10^9
1480  LET l=C/f20
1490  LET Ga1=Ga/10 : Ga2=CINT(10^Ga1)
1500  LET Lp1=Lp/10 : Lp2=10^Lp1
1510  LET Pp=Pp*10^3
1520  LET Ae=CSNG(Ga2*l^2/(4*PI))
1530  LET Rs=Rs*10^3*.914
1540 LET sec=CINT(1/COS(A.B*PI/180))
1550  LET T=T*10^-9
1560  PRINT : PRINT " FROM FIG 13.3 (SKOLNIK Pg. 475) YOU CAN FIND THE CROSS SECTION SINCE
 YOU KNOW :"
1570  PRINT : PRINT " THE GRAZING ANGLE=";sec;" & THE POLARIZATION"
1580  PRINT : PRINT " ENTER THE CROSS SECTION So IN db"
1590  INPUT So : So1=So/10 : So2=10^So1
1600 LET S=CSNG(Pp*Ga2*RCS*Ae/((4*PI)^2*Rs^4*Lp2))
1610LETC1=CSNG(Pp*Ga2*Ae*So2*(A.B*PI/180)*(C*T/2)*sec/((4*PI)^2*Rs^3*(Lp2/2)))
1620  LET SC=S/C1
1630 LET SC=CSNG(10*.4342945**LOG(SC))
1640  PRINT : PRINT " 1(b). (S/C)m=";SC,"db"; " : SINGLE PULSE SIGNAL-TO-CLUTTER RATIO AT
 THE RADARRECEIVER INPUT"
1650  LPRINT : LPRINT " 1(b). (S/C)m=";SC;"db"; " : SINGLE PULSE SIGNAL-TO-CLUTTER RATIO AT
```

```
THE RADAR RECEIVER INPUT"
1660 RETURN
1670'*****************************************
1680 ' CALCULATION & PRINTOUT FOR PART (c)
1690'*****************************************
1700 PRINT : PRINT : PRINT " PART (c)"
1710 PRINT "--------"
1720 LPRINT : LPRINT : LPRINT " PART (c)"
1730 LPRINT "--------"
1740 PRINT : PRINT " FROM TABLE 11.1 (SKOLNIK Pg.426) SINCE YOU KNOW THE WEIGHTING
FILTER YOU USE, YOU CAN FIND :"
1750 INPUT "a. THE PEAK SIDELOBE SLL IN db",SLL
1760 INPUT "b. THE LOSS IN db",LOSS
1770 INPUT "c. MAINLOBE WIDTH (relative) M.W",M.W
1780 LET f10=f10*10^9
1790 LET W=f20-f10
1800 LET Tc=T/(T*W)*M.W
1810 LETA=CSNG(10*.4342945**LOG(2*T*W)-LOSS)
1820 LET SC1=SC+A
1830 PRINT : PRINT " 1(c). Tc=";Tc;"sec."; " : 3 db WIDTH OF THE COMPRESSED PULSE"
1840 PRINT : PRINT " 2(c). (S/C)out=";SC1;"db"; " : SIGNAL-MEAN CLUTTER POWER"
1850 LPRINT : LPRINT " 1(c). Tc=";Tc;"sec."; " : 3 db WIDTH OF THE COMPRESSED PULSE"
1860 LPRINT : LPRINT " 2(c). (S/C)out=";SC1;"db"; " : SIGNAL-MEAN CLUTTER POWER"
1870 RETURN
1880'*****************************************
1890 ' CALCULATION & PRINTOUT FOR PART (d)
1900'*****************************************
1910 PRINT : PRINT : PRINT " PART (d)"
1920 PRINT "--------"
1930 LPRINT : LPRINT : LPRINT " PART (d)"
1940 LPRINT "--------"
1950 LET ns=A.B*fp/(6*Wm)
1960 LET n=ns*(300/60)*Ts
1970 PRINT : PRINT " FROM FIG 2.8(a) (SKOLNIK Pg. 31) YOU CAN FIND THE I1(n) SINCE YOU KNOW
:"
```

```
1980  PRINT : PRINT " a. #OF HITS=";n
1990  PRINT : PRINT " b. YOU 'RE IN POST DETECTION CASE"
2000  PRINT : PRINT " ENTER THE INTEGRATION IMPR. FACTIOR I1 "
2010  INPUT I1
2020 LET I1=CINT(10*.4342945**LOG(I1))
2030  LET B=SC1+I1
2040  PRINT : PRINT " 1(d). n=";n; " : #OF HITS"
2050  PRINT : PRINT " 2(d). I1(n)=";I1;"db"; " : INTEGRATION IMPR. FACTOR"
2060  PRINT : PRINT " 3(d). (S/C)=(S/C)out+I1(n)=";B;"db"; " : INTEGR. IMPROVEMENT"
2070  LPRINT : LPRINT " 1(d). n=";n; " : #OF HITS"
2080  LPRINT : LPRINT " 2(d). I1(n)=";I1;"db"; " : INTEGRATION IMPR. FACTOR"
2090  LPRINT : LPRINT " 3(d). (S/C)=(S/C)out+I1(n)=";B;"db"; " : INTEGR. IMPROVEMENT"
2100  RETURN
```

## PROBLEM#8

GIVEN

1. f10= 9.5 f20= 10 GHz : RANGE OF THE OPERATING FREQ.
2. Pp= 500 KW : PEAK POWER
3. fp= 1500 Hz : P.R.F
4. T= 500 nsec. : PULSEWIDTH
5. Ga= 35 db : ANTENNA GAIN
6. A.B= 2.4 Deg. : AZIMUTH BEAMWIDTH
7. Wm= 300 RPM : ANTENNA SCAN RATE
8. Lp= 5 db : PLUMBING LOSSES
9. Rx= 7.5 db : Rx NOISE FIGURE
10. Ha= 2000 ft : AIRCRAFT'S ALTITUDE
11. Rs= 16 Kyards : RANGE TO SUBMARINE
12. RCS= 1 sq.m : PERISCOP'S RCS
13. t1fa= 2 sec. : AVERAGE DURATION OF THE SEA CLUTTER SPIKES
14. Tfa= 100 sec. : FALSE ALARM TIME
15. Ts= 5 sec. : POST DETECTION INTEGRATION PERIOD

PART (a)

1(a). Pfa= .02 : FALSE ALARM PROBABILITY

2(a). THRESHOLD= 12.5 db : LEVEL THAT THE THRESH. MUST BE SET ABOVE THE MEDIAN CLUTTER TO ACHIEVE Pfa= .02

PART(b)

1(b). (S/C)m= -17.6325 db : SINGLE PULSE SIGNAL-TO-CLUTTER RATIO AT THE RADAR RECEIVER INPUT

PART (c)

1(c). Tc= .000000003 sec. : 3 db WIDTH OF THE COMPRESSED PULSE

2(c). (S/C)out= 8.0172 db : SIGNAL-MEAN CLUTTER POWER

**PART (d)**

1(d). n= 50 : #OF HITS

2(d). II(n)= 14 db : INTEGRATION IMPR. FACTOR

3(d). (S/C)=(S/C)out+II(n)= 22.0172 db: INTEGR. IMPROVEMENT

```
30   GOSUB 90 : GOSUB 890  : GOSUB 1100
40   PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/
50   INPUT D$
60   IF LEFT$(D$, 1)="Y" OR LEFT$(D$, 1)="y"  THEN 30
70   END
80   '*********************************
90                INPUTS THE DATA
100  '*********************************
110  PRINT : PRINT " ENTER THE OPERATING FREQ. f0 IN GHz"
120  INPUT f0 : PRINT : PRINT "  1. f0=";f0;"GHz"
130  PRINT : PRINT " ENTER THE PEAK POWER Pp IN MW"
140  INPUT Pp : PRINT : PRINT "  2. Pp=";Pp;"MW"
150  PRINT : PRINT " ENTER THE ANTENNA GAIN Ga IN db"
160  INPUT Ga : PRINT : PRINT "  3. Ga=";Ga;"db"
170  PRINT : PRINT " ENTER THE AZIMUTH BEAMWIDTH A.B IN Deg."
180  INPUT A.B : PRINT : PRINT "  4. A.B=";A.B;"Deg."
190  PRINT : PRINT " ENTER THE ELEVATION COVERAGE ECmin,ECmax IN Deg."
200  INPUT ECmin,ECmax : PRINT : PRINT "5. ECmin=";ECmin; " ECmax=";ECmax;" Deg."
210  PRINT : PRINT " ENTER THE ANTENNA SCAN RATE Wm IN RPM"
220  INPUT Wm : PRINT : PRINT "  6. Wm=";Wm;"RPM"
230  PRINT : PRINT " ENTER THE P.R.F fp IN Hz"
240  INPUT fp : PRINT : PRINT "  7. fp=";fp;"Hz"
250  PRINT : PRINT " ENTER THE PULSE WIDTH T IN microsec."
260  INPUT T : PRINT : PRINT "  8. T=";T;"microsec."
270  PRINT : PRINT " ENTER THE RECEIVER NOISE FIGURE F IN db"
280  INPUT F : PRINT : PRINT "  9. F=";F;"db"
290  PRINT : PRINT " ENTER THE AIRCRAFT'S RADAR CROSS SECTION RCS IN dbsm"
300  INPUT RCS : PRINT : PRINT "  10. RCS=";RCS;"dbsm"
310  PRINT : PRINT " ENTER THE RANGE OF THE AIRCRAFT R IN Km"
320  INPUT R : PRINT : PRINT "  11. R=";R;"Km"
330  PRINT : PRINT " ENTER THE CHAFF RMS VELOCITY SPREAD Su IN m/sec."
340  INPUT Su : PRINT : PRINT "  12. Su=";Su;"m/sec."
350  PRINT : PRINT " ENTER THE CLUTTER-TARGET SIGNAL RATIO (S/N)out IN db"
```

```
360  INPUT SNout : PRINT : PRINT " 13. SNout=";SNout;"db"
370  PRINT : PRINT " IS THE INPUT DATA CORRECT Y/N?"
380  INPUT A$
390  IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y" THEN 870
400  PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
410  PRINT : PRINT " 1. THE OPERATING FREQ.?"
420  PRINT : PRINT " 2. THE PEAK POWER?"
430  PRINT : PRINT " 3. THE ANTENNA GAIN?"
440  PRINT : PRINT " 4. THE AZIMUTH BEAMWIDTH?"
450  PRINT : PRINT " 5. THE RANGE OF THE ELEVATION COVERAGE?"
460  PRINT : PRINT " 6. THE ANTENNA SCAN RATE?"
470  PRINT : PRINT " 7. THE P.R.F?"
480  PRINT : PRINT " 8. THE PULSE WIDTH?"
490  PRINT : PRINT " 9. THE RECEIVER NOISE FIGURE?"
500  PRINT : PRINT " 10. THE AIRCRAFT'S RADAR CROSS SECTION?"
510  PRINT : PRINT " 11. THE RANGE OF THE AIRCRAFT?"
520  PRINT : PRINT " 12. THE CHAFF'S RMS VELOCITY SPREAD?"
530  PRINT : PRINT " 13. THE CLUTTER-TARGET SIGNAL RATIO?"
540  INPUT C$
550  IF C$="1"  THEN PRINT : PRINT " ENTER THE OPERATING FREQ. f0 IN GHz"
560  IF C$="1"  THEN INPUT f0 : PRINT : PRINT " 1. f0=";f0;"GHz" : GOTO 810
570  IF C$="2"  THEN PRINT : PRINT " ENTER THE PEAK POWER Pp IN MW"
580  IF C$="2"  THEN INPUT Pp : PRINT : PRINT " 2. Pp=";Pp;"MW" : GOTO 810
590  IF C$="3"  THEN PRINT : PRINT " ENTER THE ANTENNA GAIN Ga IN db"
600  IF C$="3"  THEN INPUT Ga : PRINT : PRINT " 3. Ga=";Ga;"db" : GOTO 810
610  IF C$="4"  THEN PRINT : PRINT " ENTER THE AZIMUTH BEAMWIDTH A.B IN Deg."
620  IF C$="4"  THEN INPUT A.B . PRINT : PRINT " 4. A.B=";A.B;"Deg." : GOTO 810
630  IF C$="5"  THEN PRINT : PRINT " ENTER THE ELEVATION COVERAGE ECmin,ECmax IN Deg."
640  IF C$="5"  THEN INPUT ECmin,ECmax : PRINT : PRINT " 5. ECmin=";ECmin; "
 ECmax=";ECmax;" Deg." : GOTO 810
650  IF C$="6"  THEN PRINT : PRINT " ENTER THE ANTENNA SCAN RATE Wm IN RPM"
660  IF C$="6"  THEN INPUT Wm : PRINT : PRINT " 6. Wm=";Wm;"RPM" : GOTO 810
670  IF C$="7"  THEN PRINT : PRINT " ENTER THE P.R.F fp IN Hz"
680  IF C$="7"  THEN INPUT fp : PRINT : PRINT " 7. fp=";fp;"Hz" : GOTO 810
690  IF C$="8"  THEN PRINT : PRINT " ENTER THE PULSE WIDTH T IN microsec."
```

```
700   IF C$="8"   THEN INPUT T : PRINT : PRINT " 8. T=";T;"microsec." : GOTO 810
710   IF C$="9"   THEN PRINT : PRINT " ENTER THE RECEIVER NOISE FIGURE F IN db"
720   IF C$="9"   THEN INPUT F : PRINT : PRINT " 9. F=";F;"db" : GOTO 810
730   IF C$="10"   THEN PRINT : PRINT " ENTER THE AIRCRAFT'S RADAR CROSS SECTION RCS IN
 dbsm"
740   IF C$="10"   THEN INPUT RCS : PRINT : PRINT " 10. RCS=";RCS;"dbsm" : GOTO 810
750   IF C$="11"   THEN PRINT : PRINT " ENTER THE RANGE OF THE AIRCRAFT R IN Km"
760   IF C$="11"   THEN INPUT R : PRINT : PRINT " 11. R=";R;"Km" : GOTO 810
770   IF C$="12"   THEN PRINT : PRINT " ENTER THE CHAFF RMS VELOCITY SPREAD Su IN m/sec."
780   IF C$="12"   THEN INPUT Su : PRINT : PRINT " 12. Su=";Su;"m/sec." : GOTO 810
790   IF C$="13"   THEN PRINT : PRINT " ENTER THE CLUTTER-TARGET SIGNAL RATIO (S/N)out IN
 db"
800   IF C$="13"   THEN INPUT SNout : PRINT : PRINT " 13. SNout=";SNout;"db" : GOTO 810
810   PRINT : PRINT " IS EVERYTHING O.K NOW?"
820    INPUT B$
830   IF LEFT$(B$,1)="Y" OR LEFT$(B$,1)="y"   THEN GOTO 870
840   PRINT : PRINT " WHAT DO YOU WANT TO CHANGE AGAIN?"
850   PRINT : PRINT " HIT ANY KEY IN YOUR KEYBOARD AND EVERYTHING WILL WORK FOR YOU
 MALAKA"
860    INPUT F$  : GOTO 410
870    RETURN
880  '*********************************
890    '       PRINTS THE INPUT DATA
900  '*********************************
910   LPRINT : LPRINT TAB(30); " PROBLEM #9"
920   LPRINT TAB(30); " ---------"
930    LPRINT : LPRINT " G I V E N"
940   LPRINT " ---------"
950   LPRINT : LPRINT " 1. f0=";f0;"GHz" SPC(15); " : OPERATING FREQ."
960   LPRINT : LPRINT " 2. Pp=";Pp;"MW" SPC(18); " : PEAK POWER"
970   LPRINT : LPRINT " 3. Ga=";Ga;"db" SPC(17); " : ANTENNA GAIN"
980   LPRINT : LPRINT " 4. A.B=";A.B;"Deg." SPC(13); " : AZIMUTH BEAMWIDTH"
990   LPRINT : LPRINT " 5. ECmin=";ECmin; " ECmax=";ECmax;" Deg."; " : RANGE OF ELEVATION
 COVERAGE"
1000  LPRINT : LPRINT " 6. Wm=";Wm;"RPM" SPC(17); " : ANTENNA SCAN RATE"
```

```
1010  LPRINT : LPRINT " 7. fp=";fp;"Hz" SPC(16); " : P.R.F"
1020  LPRINT : LPRINT " 8. T=";T;"microsec." SPC(12); " : PULSE WIDTH"
1030  LPRINT : LPRINT " 9. F=";F;"db" SPC(19); " : RECEIVER NOISE FIGURE"
1040  LPRINT : LPRINT " 10. RCS=";RCS;"dbsm" SPC(13); " : AIRCRAFT'S RADAR CROSS SECTION"
1050  LPRINT : LPRINT " 11. R=";R;"Km" SPC(16); " : RANGE OF THE AIRCRAFT"
1060  LPRINT : LPRINT " 12. Su=";Su;"m/sec." SPC(13); " : CHAFF RMS VELOCITY SPREAD"
1070  LPRINT :LPRINT " 13. SNout=";SNout;"db" SPC(11); " : CLUTTER-TARGET SIGNAL RATIO
(S/N)out"
1080  RETURN
1090'*****************************************
1100  ' CALCULATION & PRINTOUT OF THE OUTPUT
1120'*****************************************
1130  PRINT : PRINT : PRINT " OUTPUT"
1140  PRINT " ------"
1150  LPRINT : LPRINT : LPRINT " OUTPUT"
1160  LPRINT " ------"
1170  LET C=3*10^8
1180  LET f0=f0*10^9
1190  LET l=C/f0
1200  LET PI=3.14159
1210 LET Imax=CINT(fp^2*l^2/(16*PI^2*Su)*(4))
1220 LET Imax1=CSNG(10* 4342945**LOG(Imax))
1230  PRINT : PRINT " THE BEST IMPROVEMENT THE DELAY LINE CANCELER WILL PROVIDE IS :"
1240  PRINT : PRINT " Imax=";Imax;"numeric";" OR";Imax1;"db"
1250  LPRINT : LPRINT " THE BEST IMPROVEMENT THE DELAY LINE CANCELER WILL PROVIDE IS :"
1260  LPRINT : LPRINT " Imax=";Imax;"numeric";" OR";Imax1;"db"
1270  LET SNin=-SNout-Imax1
1280  LET SNin=SNin/10 : SNin=10^SNin
1290 LET N=CSNG(RCS/(.15*l^2*SNin))
1300  PRINT : PRINT " N=";N;" : DIPOLES IN RESOLUTION CELL"
1310  LPRINT : LPRINT " N=";N;" : DIPOLES IN RESOLUTION CELL"
1320  RETURN
```

## PROBLEM#9

GIVEN

1. f0= 1.3 GHz : OPERATING FREQ.
2. Pp= 2 MW : PEAK POWER
3. Ga= 35 db : ANTENNA GAIN
4. A.B= 1.3 Deg. : AZIMUTH BEAMWIDTH
5. ECmin= .2 ECmax= 45 Deg. : RANGE OF ELEVATION COVERAGE
6. Wm= 5 RPM : ANTENNA SCAN RATE
7. fp= 360 Hz : P.R.F
8. T= 6 microsec. : PULSE WIDTH
9. F= 8 db : RECEIVER NOISE FIGURE
10. RCS= 10 dbsm : AIRCRAFT'S RADAR CROSS SECTION
11. R= 100 Km : RANGE OF THE AIRCRAFT
12. Su= 1 m/sec. : CHAFF RMS VELOCITY SPREAD
13. SNout= 10 db : CLUTTER-TARGET SIGNAL RATIO (S/N)out

OUTPUT

THE BEST IMPROVEMENT THE DELAY LINE CANCELER WILL PROVIDE IS

Imax= 175 numeric OR 22.4304 db

N= 2190750 : DIPOLES IN RESOLUTION CELL

```
10   PRINT : PRINT TAB(30); " PROBLEM #10"
20   PRINT TAB(30); " ---------"
30   GOSUB 100  : GOSUB 510
40   GOSUB 640  : GOSUB 790
50   PRINT : PRINT " DO YOU WANT TO TRY AGAIN FOR DIFFERENT OR THE SAME DATA Y/N?"
60   INPUT D$
70   IF LEFT$(D$,1)="Y" OR LEFT$(D$,1)="y"  THEN 30
80   END
90   '*********************************
100  '          INPUTS THE DATA
110  '*********************************
120  PRINT : PRINT " ENTER THE SWEEP RANGE F1,F2 OF THE HF RECEIVER IN MHz"
130  INPUT F1,F2 : PRINT : PRINT " 1. F1-F2=";F1"-"F2;"MHz"
140  PRINT : PRINT " ENTER THE TIME THAT THE RECEIVER SWEEPS THE ABOVE RANGE OF FREQ."
150  INPUT T : PRINT : PRINT " 2. T=";T;"times/sec."
160  PRINT : PRINT " ENTER THE FREQ. RESOLUTION DF IN KHz"
170  INPUT DF : PRINT : PRINT " 3. DF=";DF;"KHz"
180  PRINT : PRINT " ENTER THE RECEIVER NOISE FIGURE F IN db"
190  INPUT F : PRINT : PRINT " 4. F=";F;"db"
200  PRINT : PRINT " ENTER THE ANTENNA NOISE TEMPERATURE Te IN KELVIN"
210  INPUT Te : PRINT : PRINT " 5. Te=";Te;"KELVIN"
220  PRINT : PRINT " IS THE INPUT DATA CORRECT Y/N?"
230  INPUT A$
240  IF LEFT$(A$,1)="Y" OR LEFT$(A$,1)="y"  THEN 490
250  PRINT : PRINT " WHAT OF THE FOLLOWING DO YOU WANT TO CHANGE?"
260  PRINT : PRINT " 1. THE SWEEP RANGE?"
270  PRINT : PRINT " 2. THE TIME THE RECEIVER SWEEPS THE ABOVE RANGE?"
280  PRINT : PRINT " 3. THE FREQ. RESOLUTION?"
290  PRINT : PRINT " 4. THE RECEIVER'S NOISE FIGURE?"
300  PRINT : PRINT " 5. THE ANTENNA NOISE TEMPERATURE?"
310  INPUT C$
320  IF C$="1"  THEN PRINT : PRINT " ENTER THE SWEEP RANGE F1,F2 OF THE HF RECEIVER IN
 MHz"
330  IF C$="1"  THEN INPUT F1,F2 : PRINT : PRINT " 1. F1-F2=";F1"-"F2;"MHz" : GOTO 430
340  IF C$="2"  THEN PRINT : PRINT " ENTER THE TIME THAT THE RECEIVER SWEEPS THE ABOVE
```

```
 RANGE OF FREQ."
350   IF C$="2"   THEN INPUT T : PRINT : PRINT " 2. T=";T;"times/sec." : GOTO 430
360   IF C$="3"   THEN PRINT : PRINT " ENTER THE FREQ. RESOLUTION DF IN KHz"
370   IF C$="3"   THEN INPUT DF : PRINT : PRINT " 3. DF=";DF;"KHz" : GOTO 430
380   IF C$="4"   THEN PRINT : PRINT " ENTER THE RECEIVER NOISE FIGURE F IN db"
390   IF C$="4"   THEN INPUT F : PRINT : PRINT " 4. F=";F;"db" : GOTO 430
400   IF C$="5"   THEN PRINT : PRINT " ENTER THE ANTENNA NOISE TEMPERATURE Ta IN KELVIN"
420   IF C$="5"   THEN INPUT Ta : PRINT : PRINT " 5. Ta=";Ta;"KELVIN" : GOTO 430
430   PRINT : PRINT " IS EVERYTHING O.K NOW?"
440   INPUT B$
450   IF LEFT$(B$,1)="Y" OR LEFT$(B$,1)="y"   THEN GOTO 490
460   PRINT : PRINT " WHAT DO YOU WANT TO CHANGE AGAIN?"
470   PRINT : PRINT " HIT ANY KEY IN YOUR KEYBOARD AND EVERYTHING WILL WORK FOR YOU
 MALAKA"
480   INPUT F$   : GOTO 260
490   RETURN
500 '***********************************
510   '       PRINTS THE INPUT DATA
520 '***********************************
530   LPRINT : LPRINT TAB(30); " PROBLEM #10"
540   LPRINT TAB(30); " ----------"
550   LPRINT : LPRINT " G I V E N"
560   LPRINT " ---------"
570   LPRINT : LPRINT " 1. F1-F2=";F1"-"F2;"MHz" TAB(20); " : SWEEP RANGE OF THE HF
 RECEIVER"
580   LPRINT : LPRINT " 2. T=";T;"times/sec." TAB(20); " : TIME THAT THE RECEIVER SWEEPS THE
 ABOVE RANGE OF FREQ."
590   LPRINT : LPRINT " 3. DF=";DF;"KHz" TAB(20); " : FREQ. RESOLUTION"
600   LPRINT : LPRINT " 4. F=";F;"db" TAB(20); " :RECEIVER NOISE FIGURE"
610   LPRINT : LPRINT " 5. Ta=";Ta;"KELVIN" TAB(20);" : ANTENNA NOISE TEMPERATURE"
620   RETURN
630 '*****************************************
640   '  CALCULATION & PRINTOUT FOR PART a:
650 '*****************************************
660   LET W1=(F2-F1)/(1/T)
```

```
670  LET T1=1/(DF*10^3)
680  LET W=W1*T1*1000     'KHz
690  PRINT : PRINT : PRINT " PART a:"
700  PRINT " -------:
710  LPRINT : LPRINT : LPRINT " PART a:"
720  LPRINT " -------"
730  PRINT : PRINT " W=";W;"KHz"; " : BANDWIDTH OF THE RECEIVER'S FILTER"
740  LPRINT : LPRINT " W=";W;"KHz"; " : BANDWIDTH FOR RECEIVER'S FILTER"
750  PRINT : PRINT " T=";T1;"sec."; " : TIME DELAY FOR RECEIVER'S FILTER"
760  LPRINT : LPRINT " T=";T1;"sec."; " : TIME DELAY FOR RECEIVER'S FILTER"
770  RETURN
780 '****************************************
790  '  CALCULATION & PRINTOUT FOR PART b:
800 '****************************************
810  LET T0=Ta : F1=F/10 : F2=10^F1
820  LET Te=(F2-1)*T0 : K=1.38*10^-23
830  LET MDS=K*(Ta+Te)*(1/(2*T1))
840  LET MDS=CINT(10*.4342945**LOG(MDS))
850  LET MDS=MDS+F+30
860  PRINT : PRINT : PRINT " PART b:"
870  PRINT " -------:
880  LPRINT : LPRINT : LPRINT " PART b:"
890  LPRINT " -------"
900  PRINT : PRINT " M.D.S=";MDS;"dbm"
910  LPRINT : LPRINT " M.D.S=";MDS;"dbm"
920  RETURN
```

PROBLEM # 10

GIVEN

1. F1-F2= 2 - 32 MHz : SWEEP RANGE OF THE HF RECEIVER
2. T= 25 times/sec. : TIME THAT THE RECEIVER SWEEPS THE ABOVE RANGE OF FREQ.
3. DF= 2 KHz : FREQ. RESOLUTION
4. F= 3 db : RECEIVER NOISE FIGURE
5. To= 290 KELVIN : ANTENNA NOISE TEMPERATURE

PART a:

W= 375 KHz: BANDWIDTH OF THE RECEIVER'S FILTER

T= .0005 sec.: TIME DELAY FOR RECEIVER'S FILTER

PART b:

M.D.S=-138dbm

## LIST OF REFERENCES


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